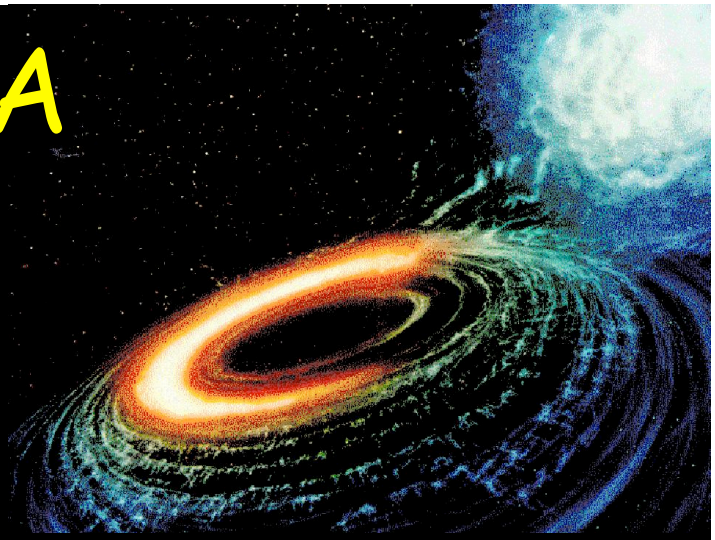
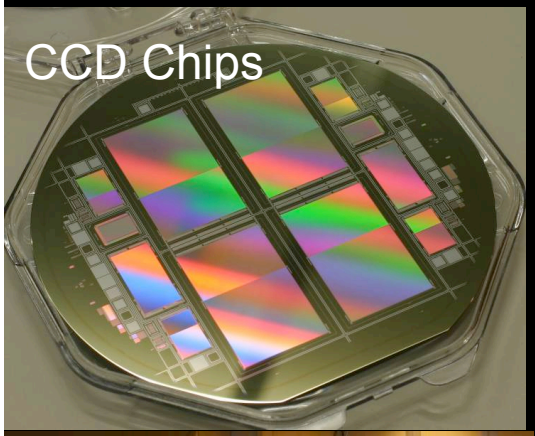
XEUS and eROSITA



Günther Hasinger

Columbia University, May 9, 2008

eROSITA @ Spektr-RG



Technology development at MPE

SXC Calorimeter

Launch 2011 (Baikonur)

eROSITA

ART-XC

Chasing Dark Energy with 100000 clusters

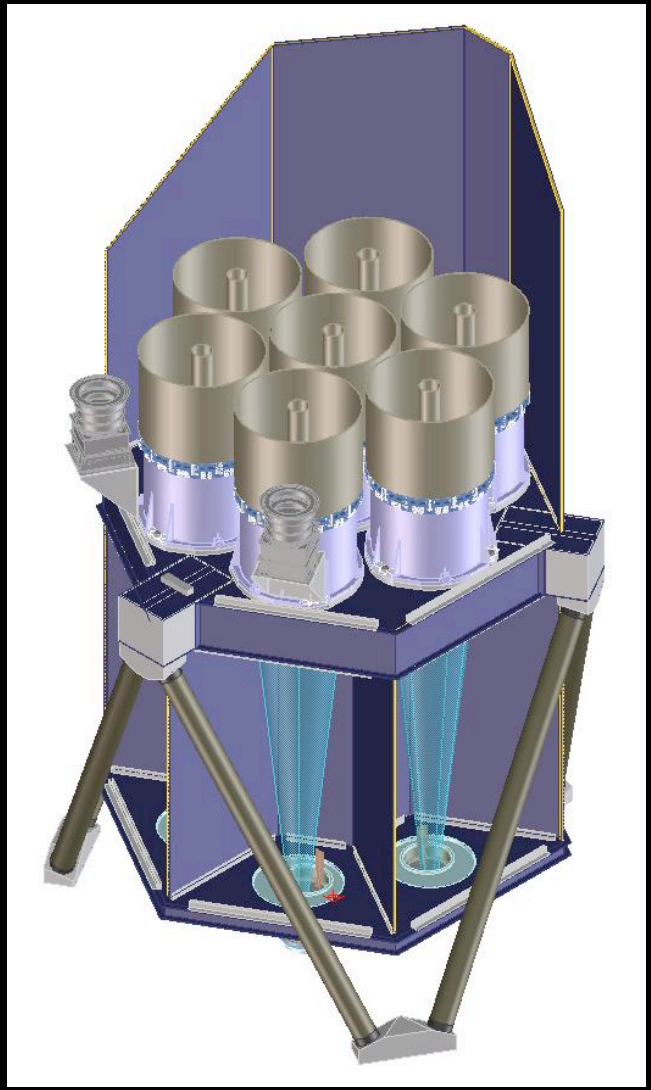
DLR

MPE

ИКИ

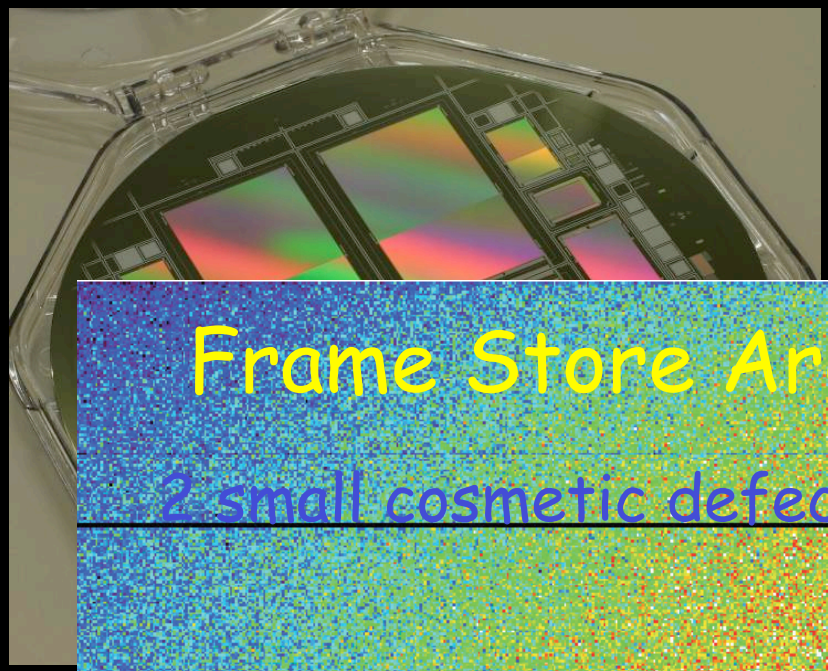
РОСКОСМОС

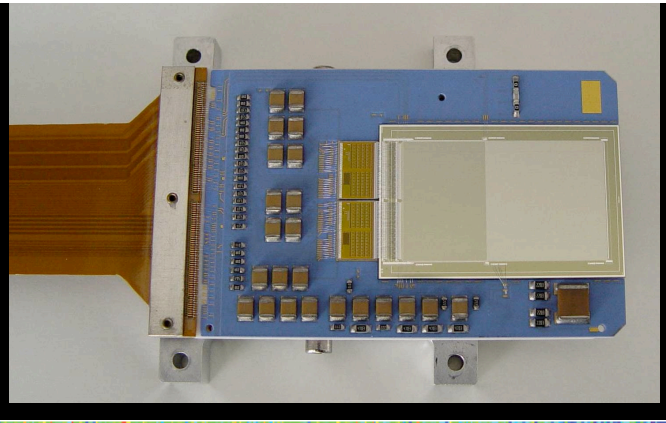
Telescope Structure



- CFRP Honeycomb Structure
  - leightweight
  - thermally stable
- Hexapod Mounting
  - no thermal/mechanical stresses induced on structure
- Sunshield
- startracker mounted on structure

New pn-CCD module





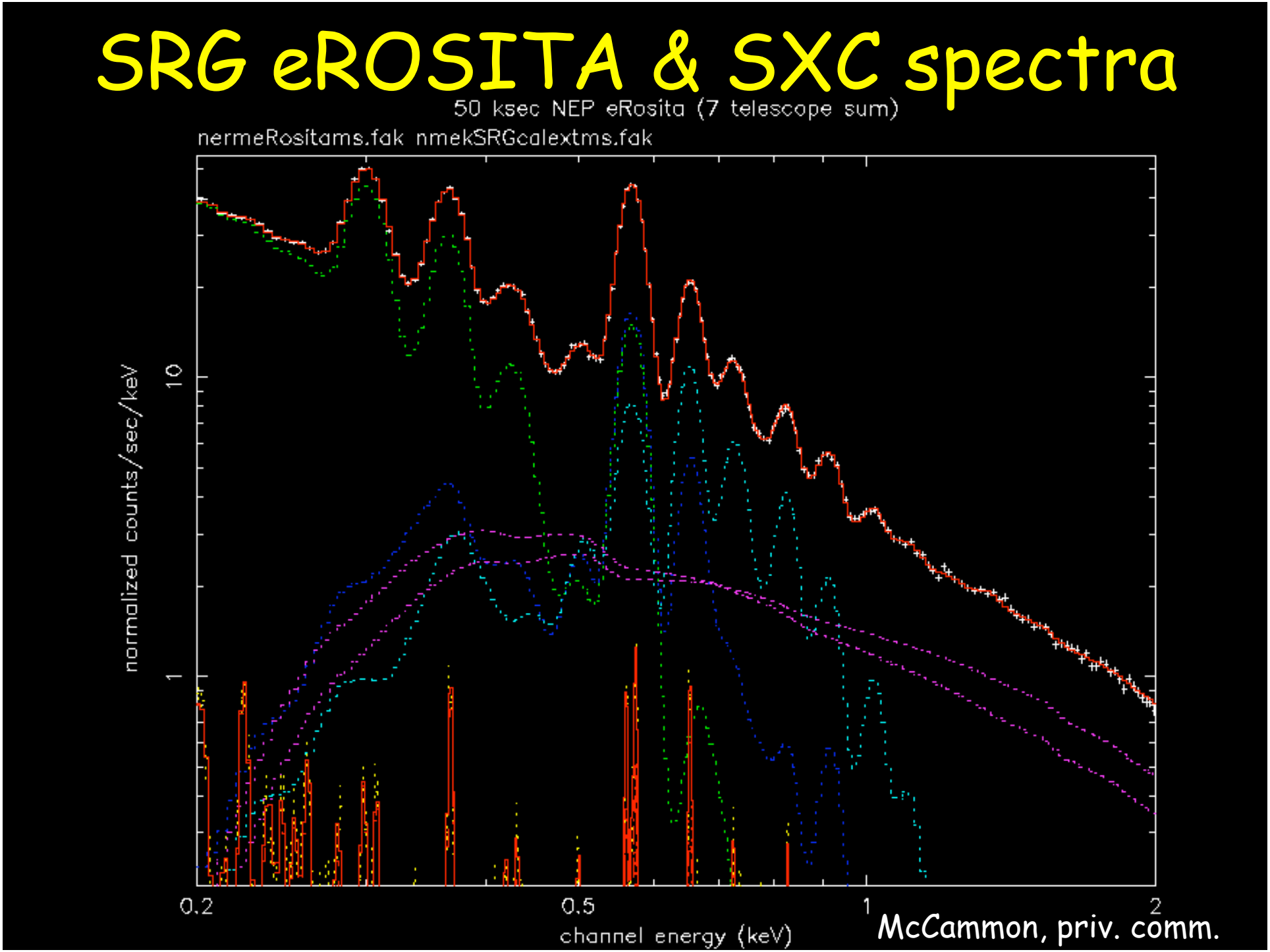
Frame Store Area

Image Area

2 small cosmetic defects

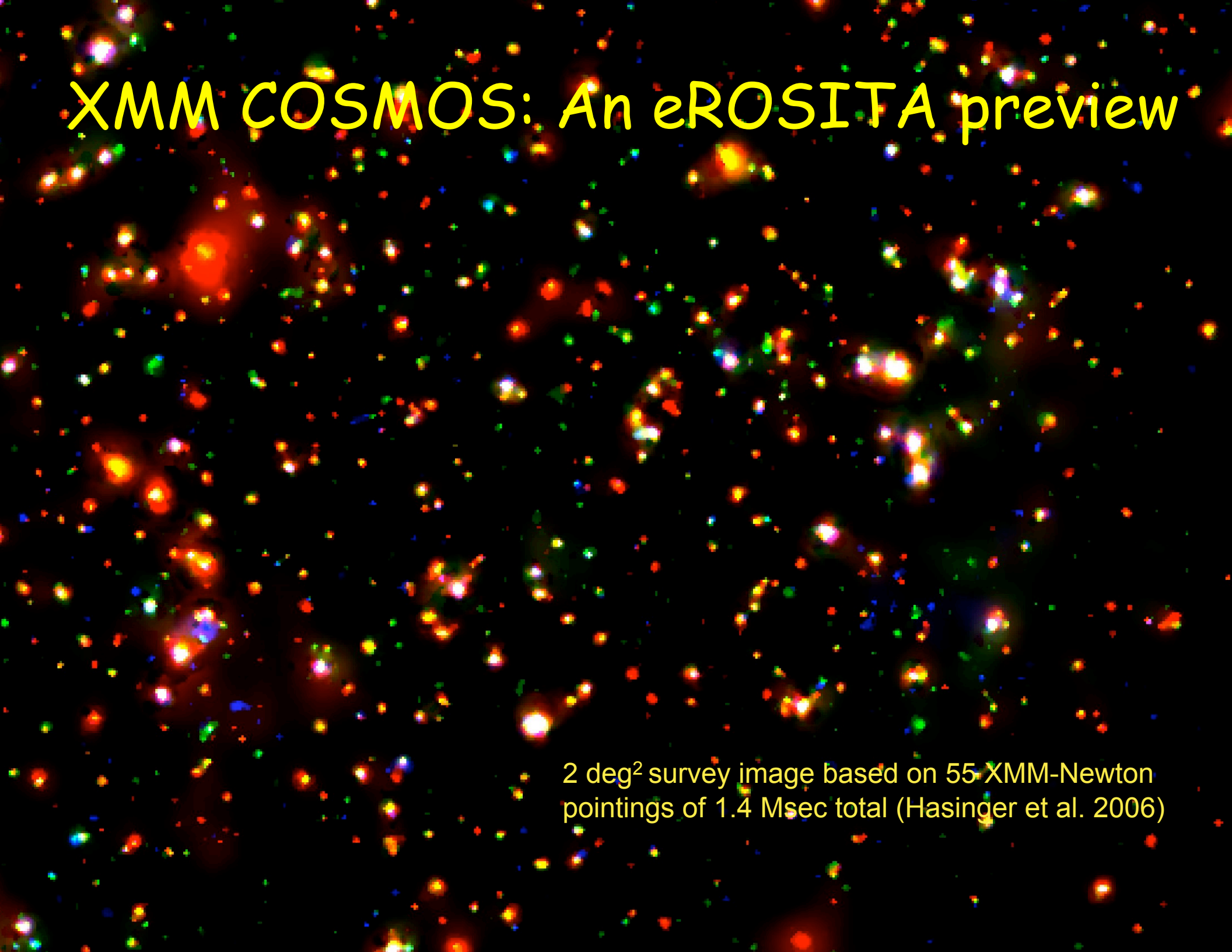
First Fe^{55} light on very first 384 x 768 Pixel eROSITA flight model chip (May 8th, 2008)

SRG eROSITA & SXC spectra



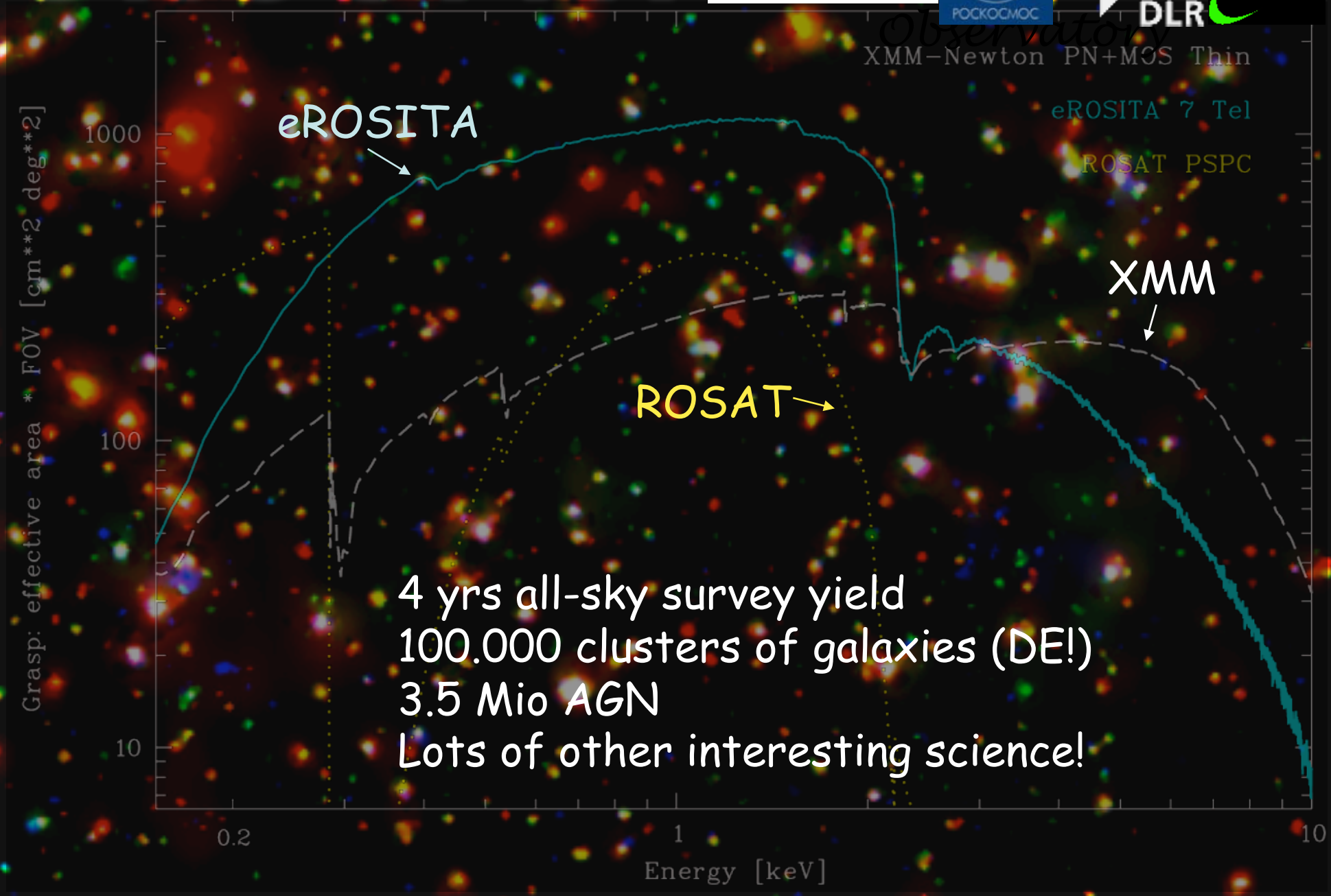
McCammon, priv. comm.

XMM COSMOS: An eROSITA preview



2 deg^2 survey image based on 55 XMM-Newton pointings of 1.4 Msec total (Hasinger et al. 2006)

eROSITA

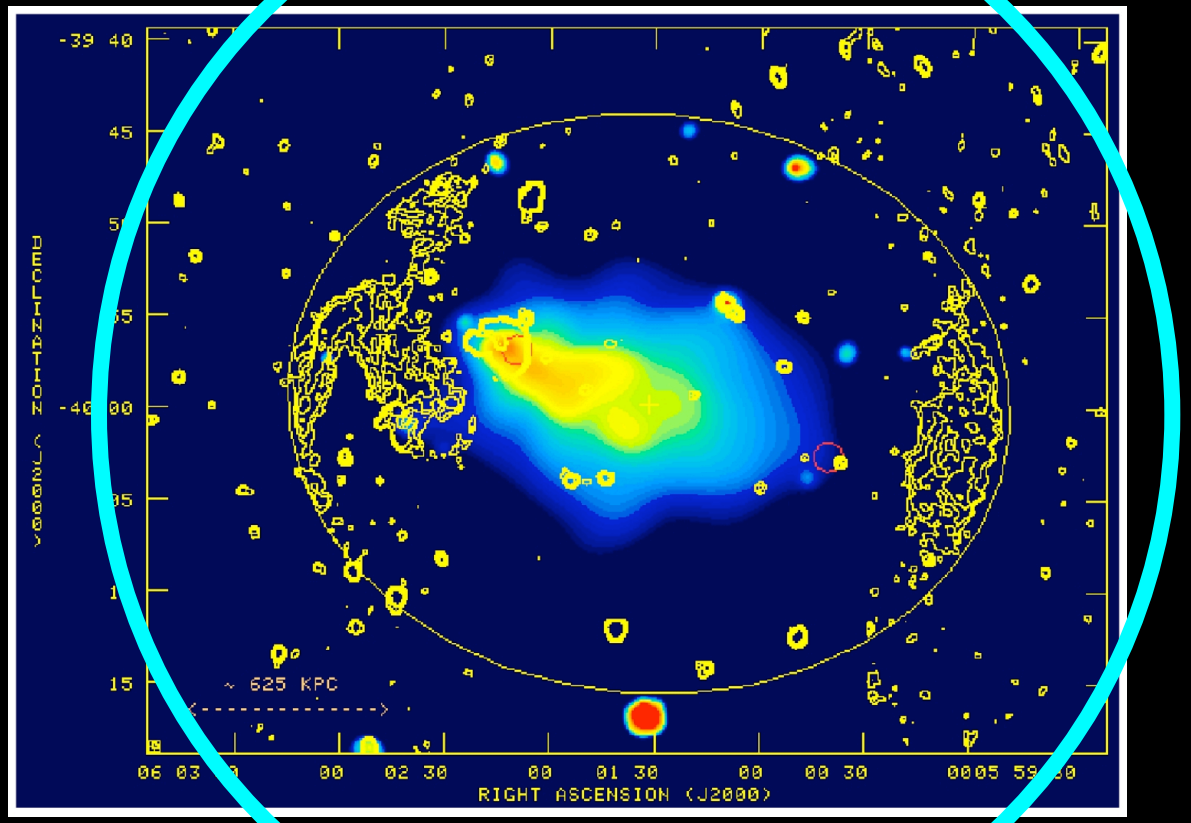


4 yrs all-sky survey yield
100.000 clusters of galaxies (DE!)
3.5 Mio AGN
Lots of other interesting science!

SRG/eROSITA Observations

- Launch 2011 (2012?)
- 0.5 yrs long pointed observations (~1 Msec each) on SXC priority targets (mainly clusters)
- 4 yrs all-sky survey (including 0.5 yrs deep s.)
- 2.5 yrs pointed observations (cluster follow-up plus open AO)
- Data will be made public

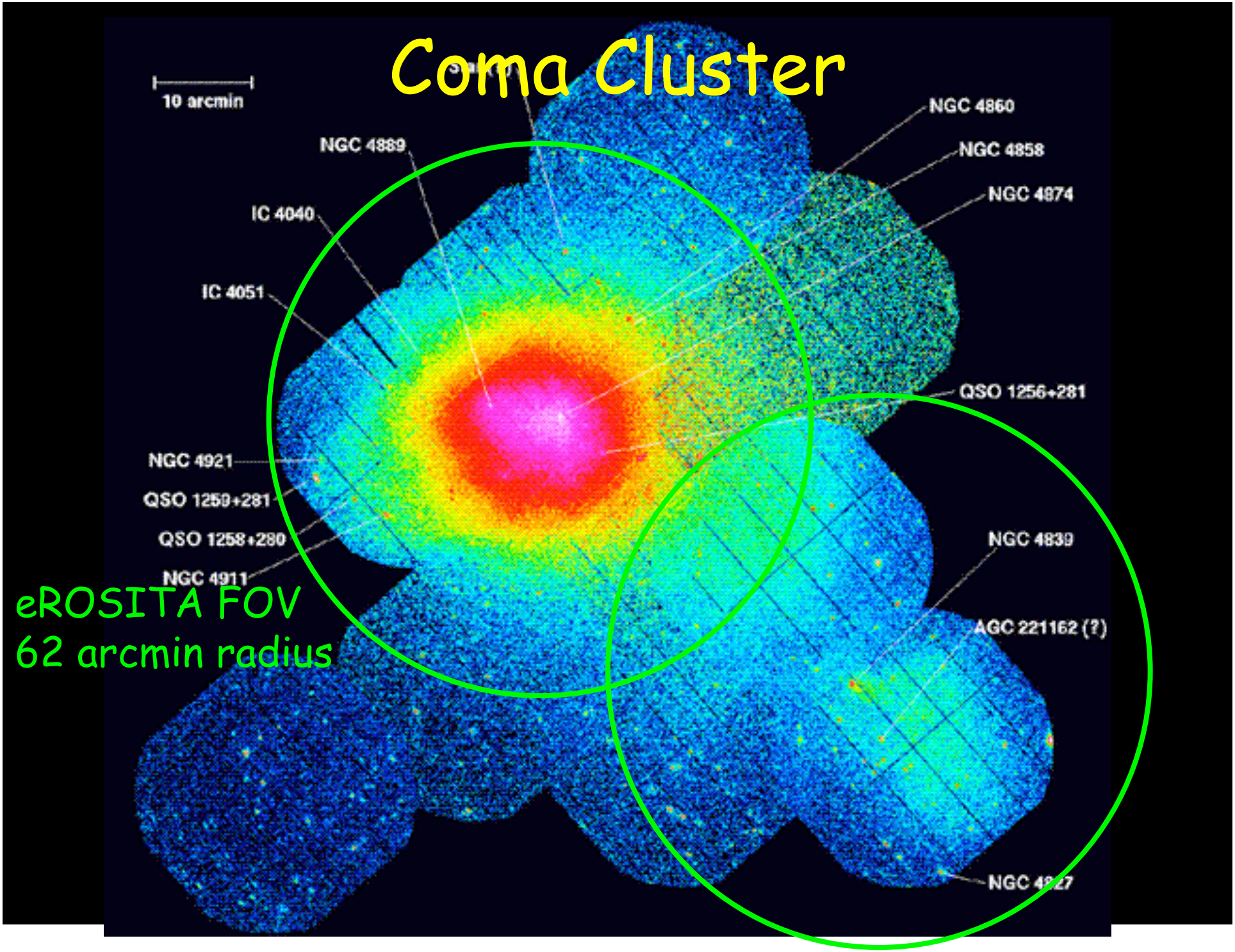
The Mpc radio arcs in Abell 3376 (z=0.046)



Smoothed ROSAT X-ray image and radio contours

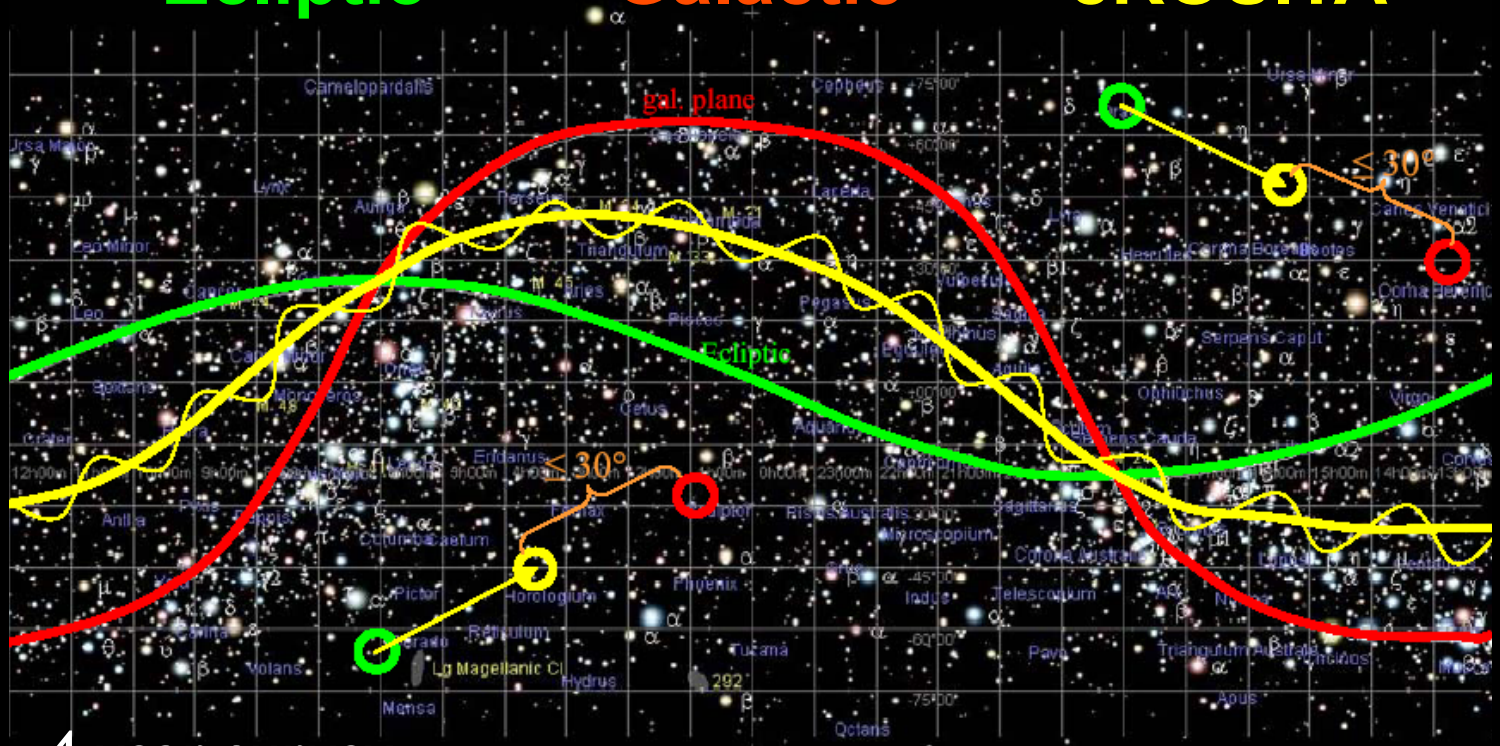
eROSITA FOV
62 arcmin radius

Bagchi, Durret, Lima Neto & Paul 2006, Science 314, 791


Coma Cluster
10 arcmin
NGC 4889
NGC 4860
NGC 4858
NGC 4874
IC 4040
IC 4051
QSO 1256+281
NGC 4921
QSO 1259+281
QSO 1258+280
NGC 4911
NGC 4839
AGC 221162 (?)
eROSITA FOV
62 arcmin radius

Survey geometry

Ecliptic **Galactic** **eROSITA**



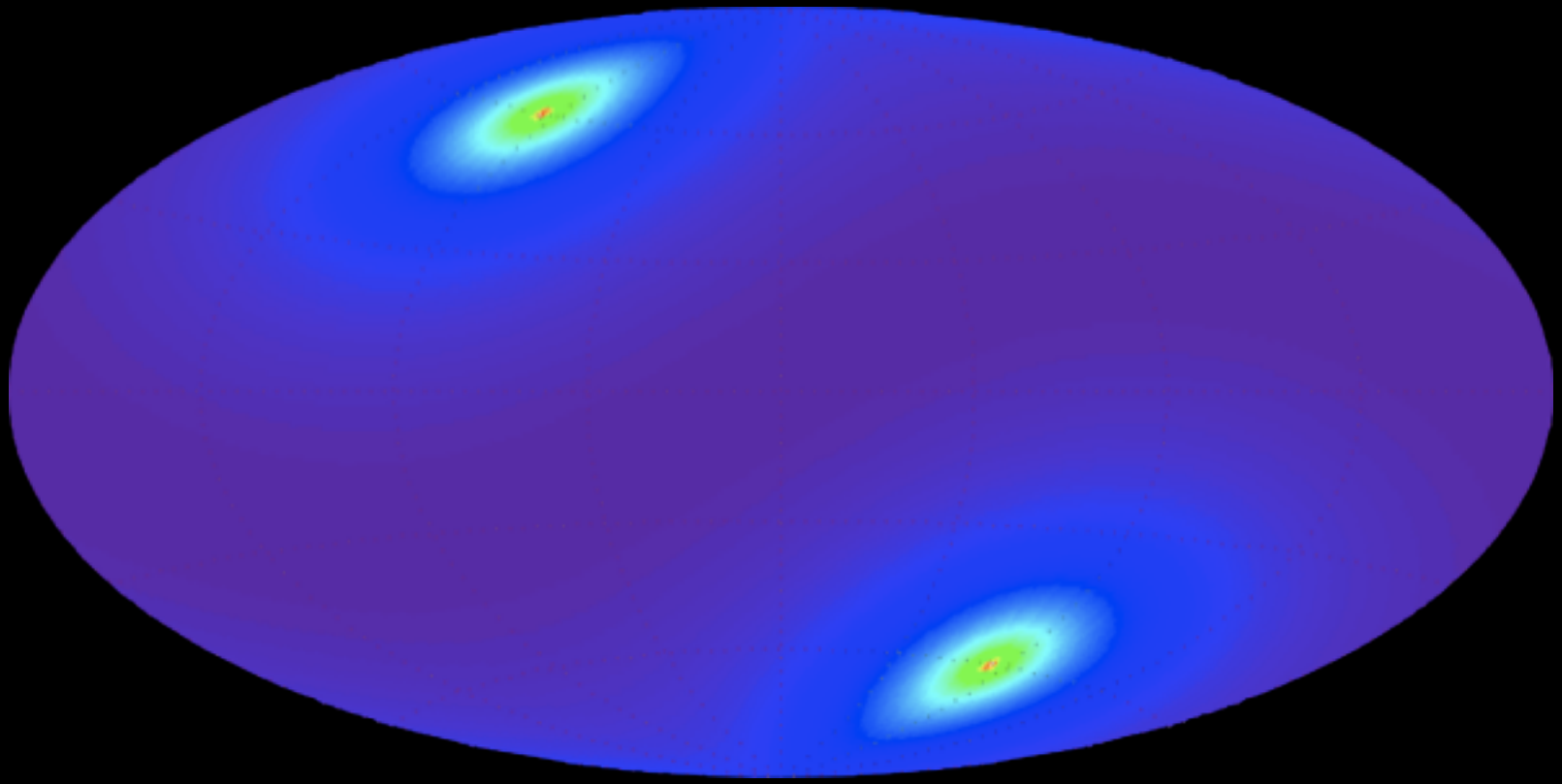
4 year survey

optimised for extragalactic sky (30,000 deg^2)

significant survey of Galactic plane (10,000 deg^2)

Pattern optimised for 400 deg^2 deep survey

Exposure map



Exposure rises towards the poles

Average exposure:

~ 1.5 ksec at SRG equator, ~ 32 ksec at poles (2 x 200 deg^2)

Simulations
(by Martin Mühlegger)

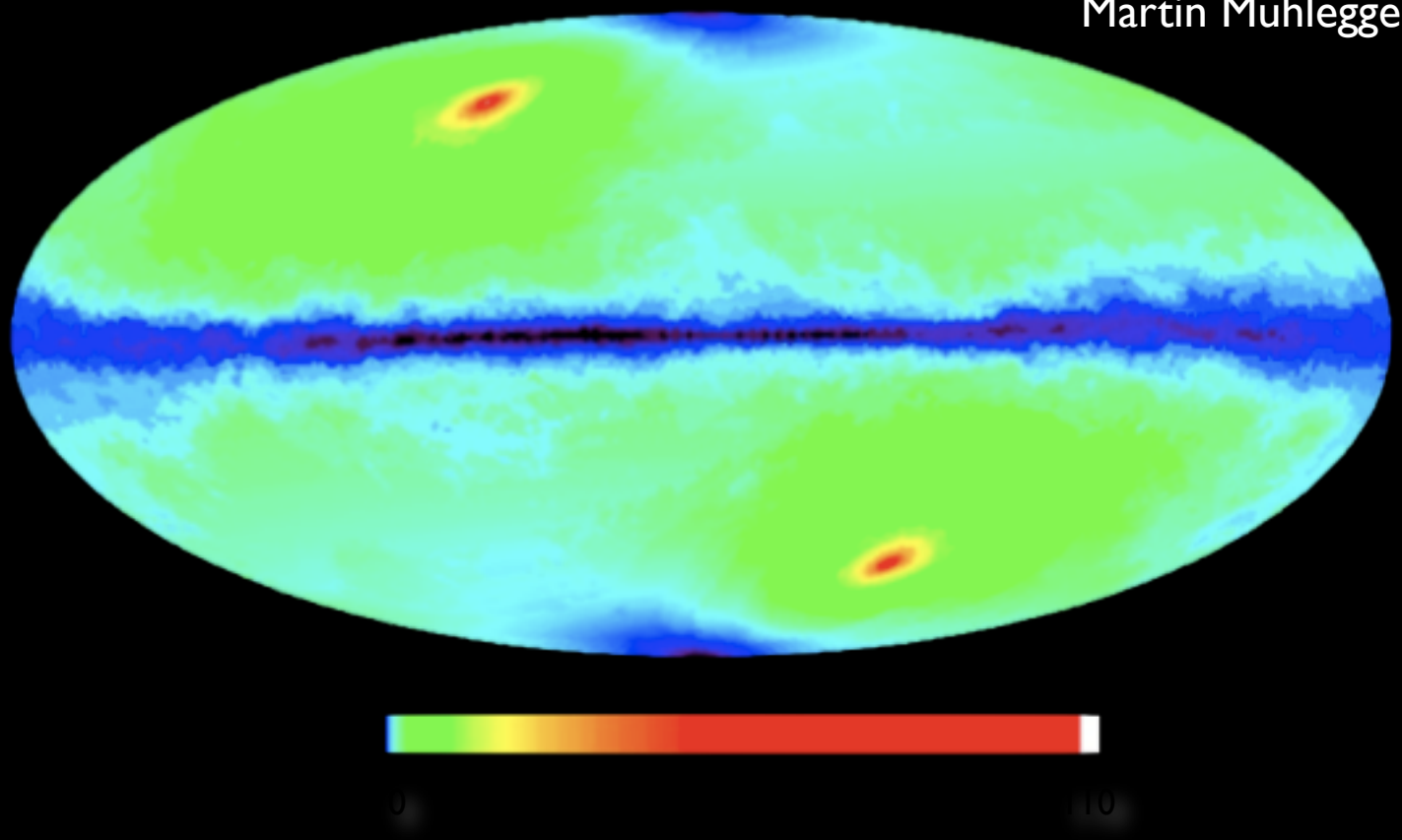
Including:

- Mass function N(M,z) → N(L_X,z), assuming given L_X-M relation
- nH distribution
- L_X-T relation: C(T,z,n_H) → C(L_X,z,n_H) → counts

Not including (so far):

- Variable CXB
- Image simulations
- Source detection tests
- Completeness

Martin Mühlegger

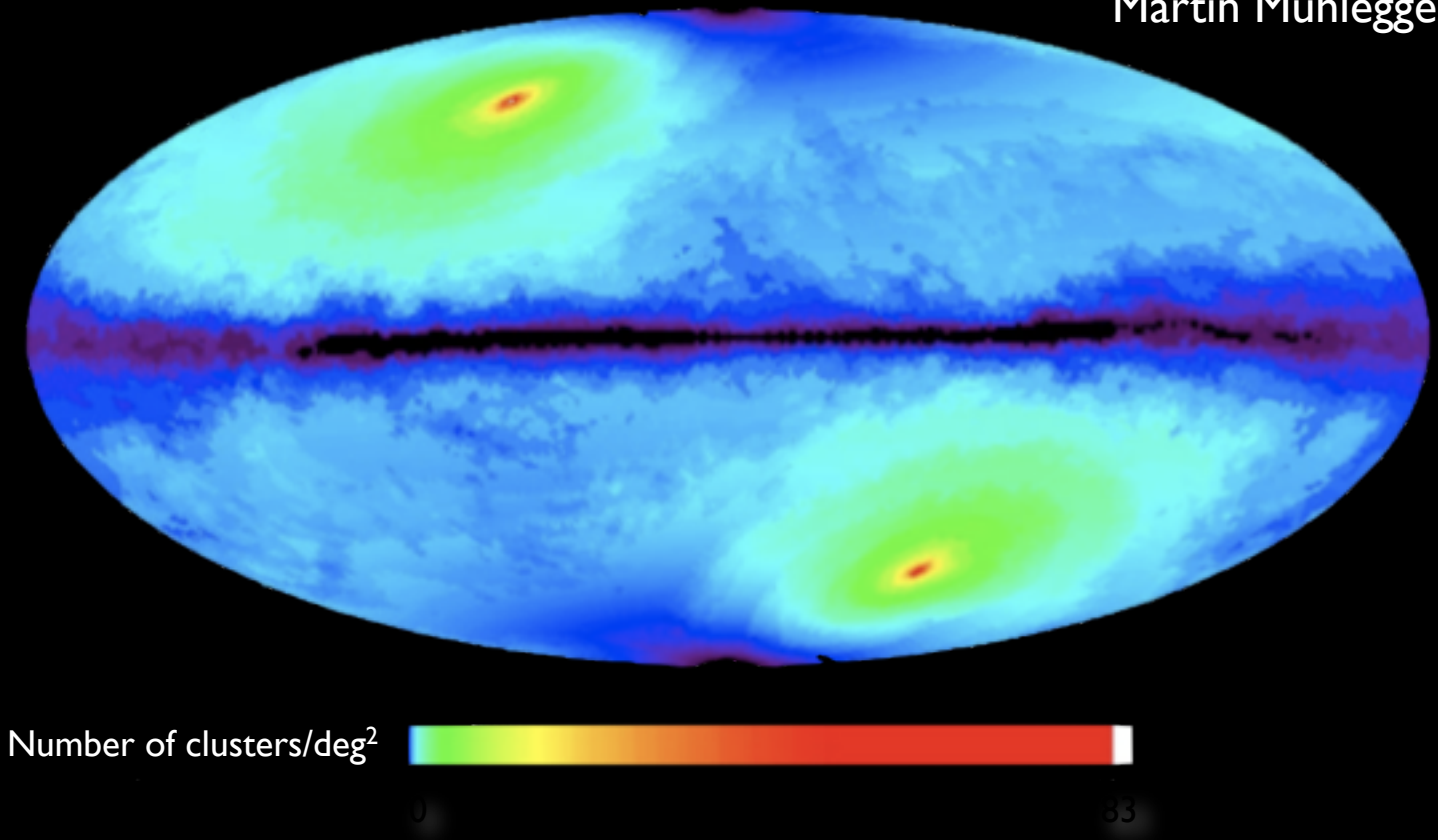


Count limit 50 counts

⇒ 179,484 clusters; 155,182 with |b| > 20°

Cluster number map

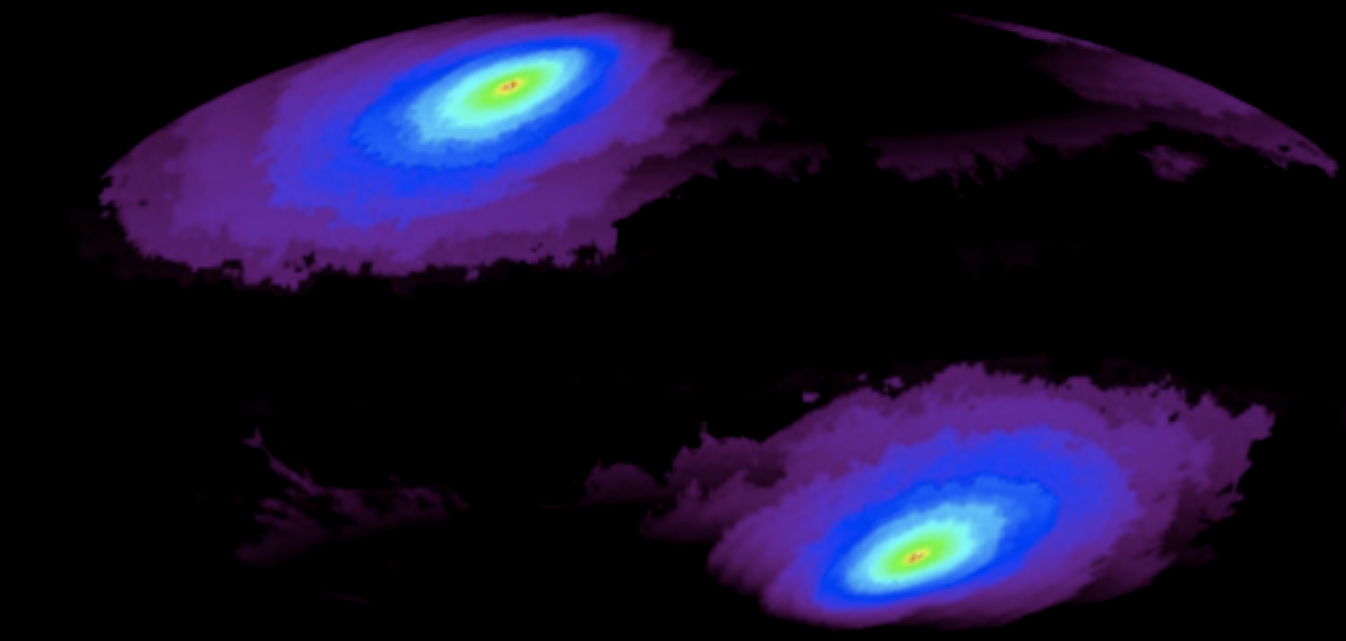
Martin Mühlegger



Count limit 100 counts

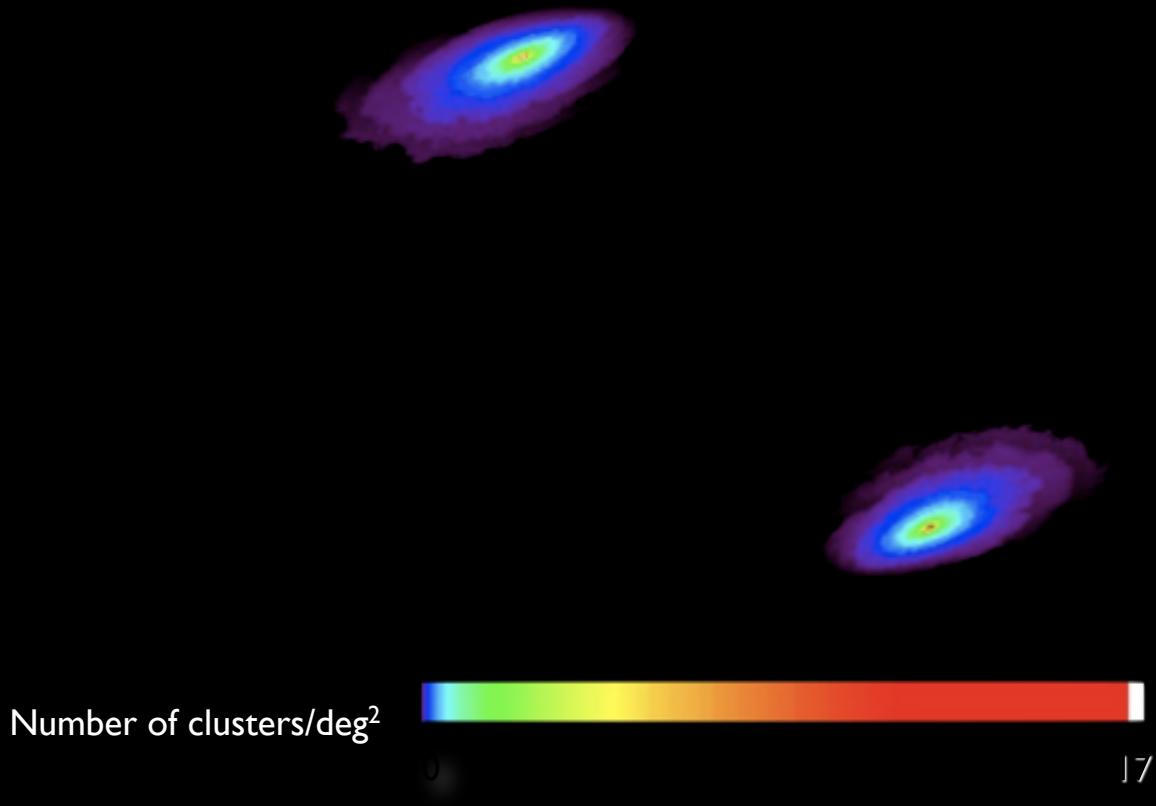
⇒ 79,912 clusters; 69,809 with |b| > 20°

Martin Mühlegger

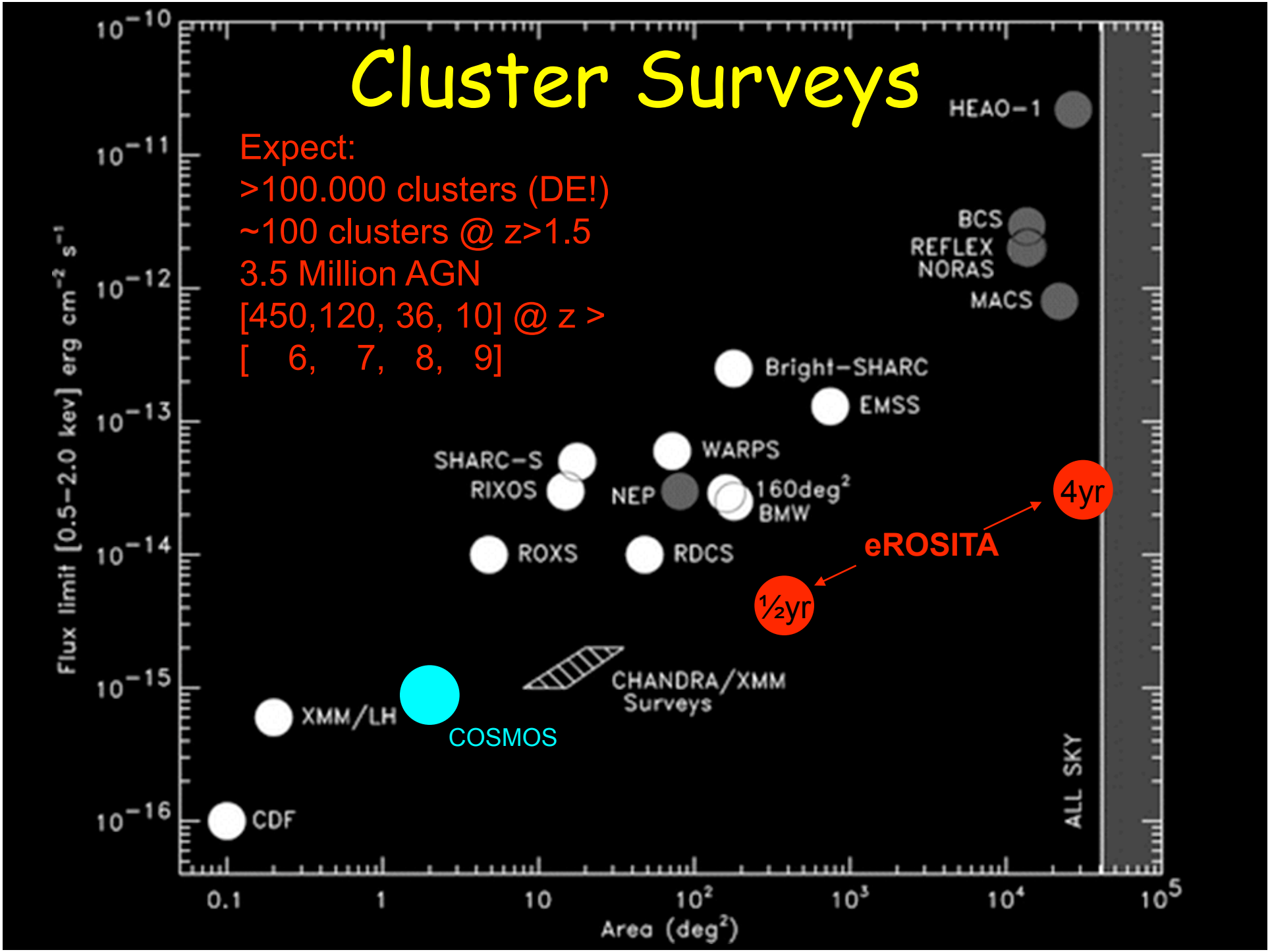


Count limit 500 counts (measure kT)
⇒ 9,935 clusters; 8,910 with |b| > 20°

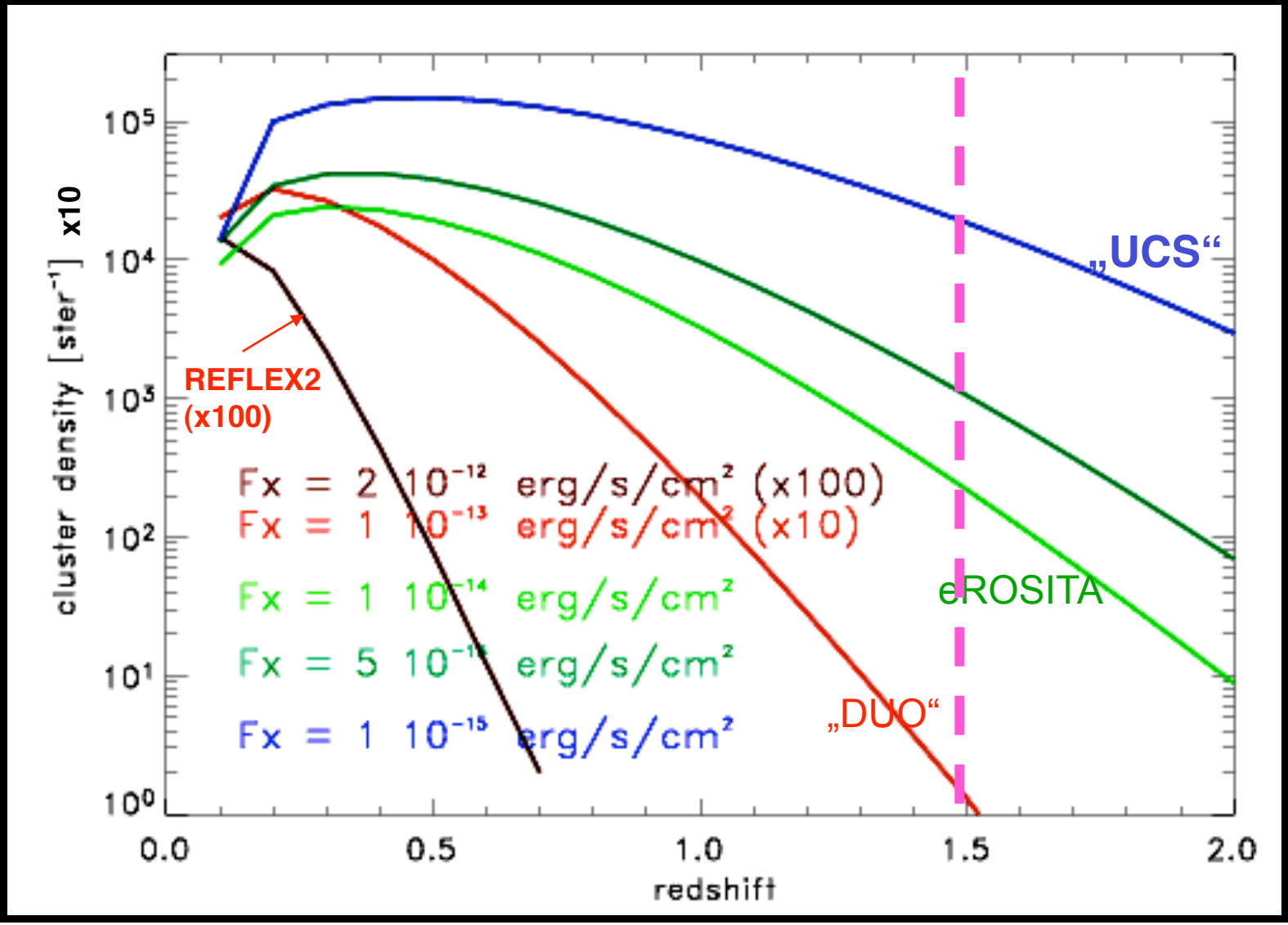
Martin Mühlegger

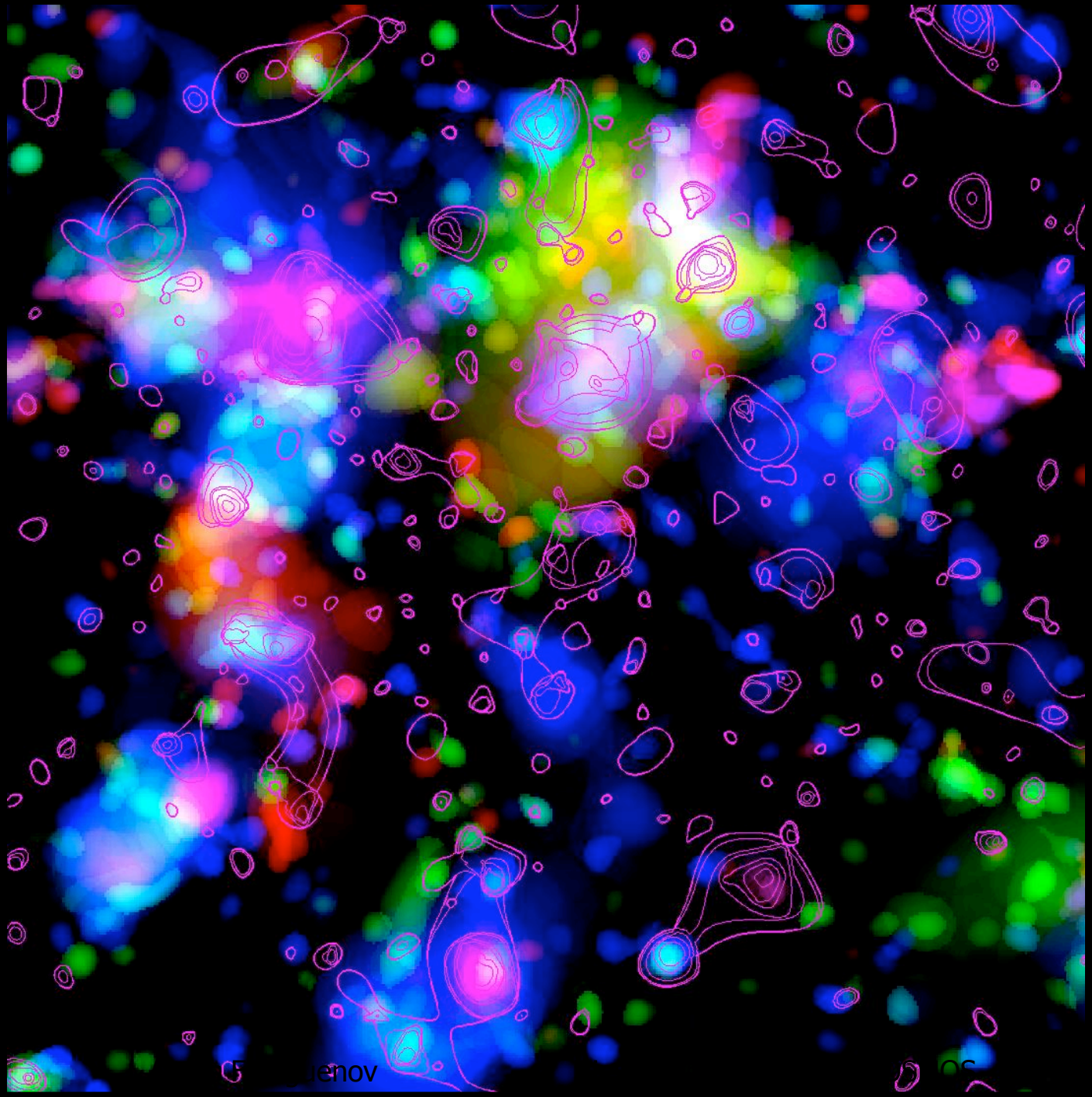


Count limit 1000 counts (measure kT, measre z from Fe line)
⇒ 3,675 clusters; 3,343 with |b| > 20°


Cluster Surveys
Expect:
>100.000 clusters (DE!)
~100 clusters @ z>1.5
3.5 Million AGN
[450,120, 36, 10] @ z >
[6, 7, 8, 9]
HEAO-1
BCS
REFLEX
NORAS
MACS
Bright-SHARC
EMSS
WARPS
SHARC-S
RIXOS
NEP
160deg²
BMW
ROXS
RDCS
4yr
eROSITA
½yr
CHANDRA/XMM
Surveys
XMM/LH
COSMOS
CDF
ALL SKY
Flux limit [0.5-2.0 kev] erg cm⁻² s⁻¹
Area (deg²)
10⁻¹⁰
10⁻¹¹
10⁻¹²
10⁻¹³
10⁻¹⁴
10⁻¹⁵
10⁻¹⁶
0.1
1
10
10²
10³
10⁴
10⁵

Prospects of cluster surveys to various depth





COSMOS

Photoz
z=0.8
z=0.6
z=0.4
z=0.2

I_{AB}<25

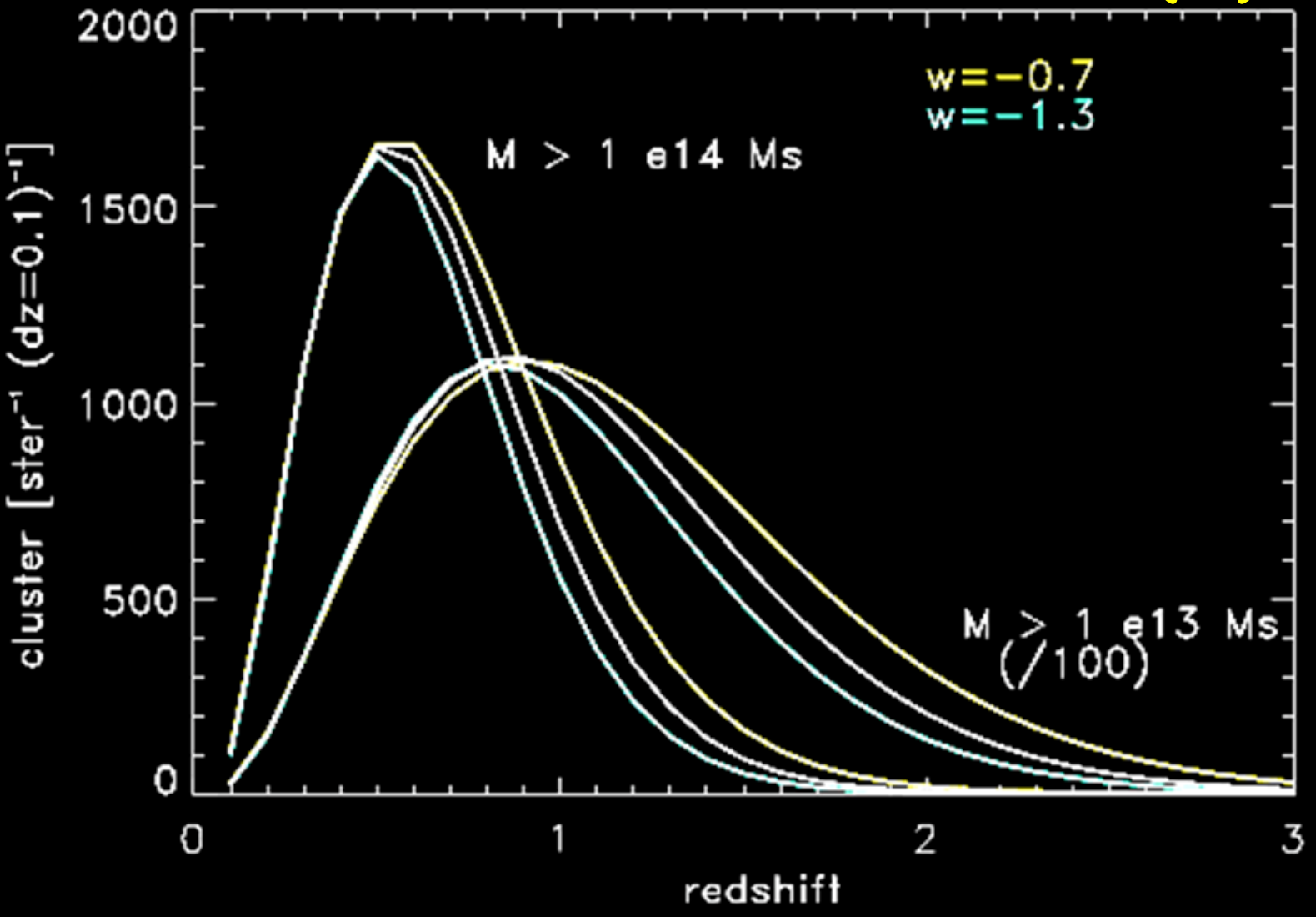
1.4Mio
galaxies

X-ray
contours

What can you do with 100,000 clusters?

1. Cluster mass function *N(M,z)* depends mainly on the matter density Ω_m and the amplitude of the primordial power spectrum σ_8 ➔ *Reiprich & Böhringer 2003*
2. Evolution *N(M,z)* gives sensitive constraints on DM and DE ➔ *Vikhlinin*
3. Cluster power spectrum amplitude and shape depend on DM and DE
4. Baryonic wiggles due to acoustic oscillations at recombination give tight constraints on space curvature
5. Cluster baryon fraction as function of z gives constraints on DM and DE ➔ *Allen*
6. Clusters provide direct distance measurements due to combined X-ray and SZ-measurements

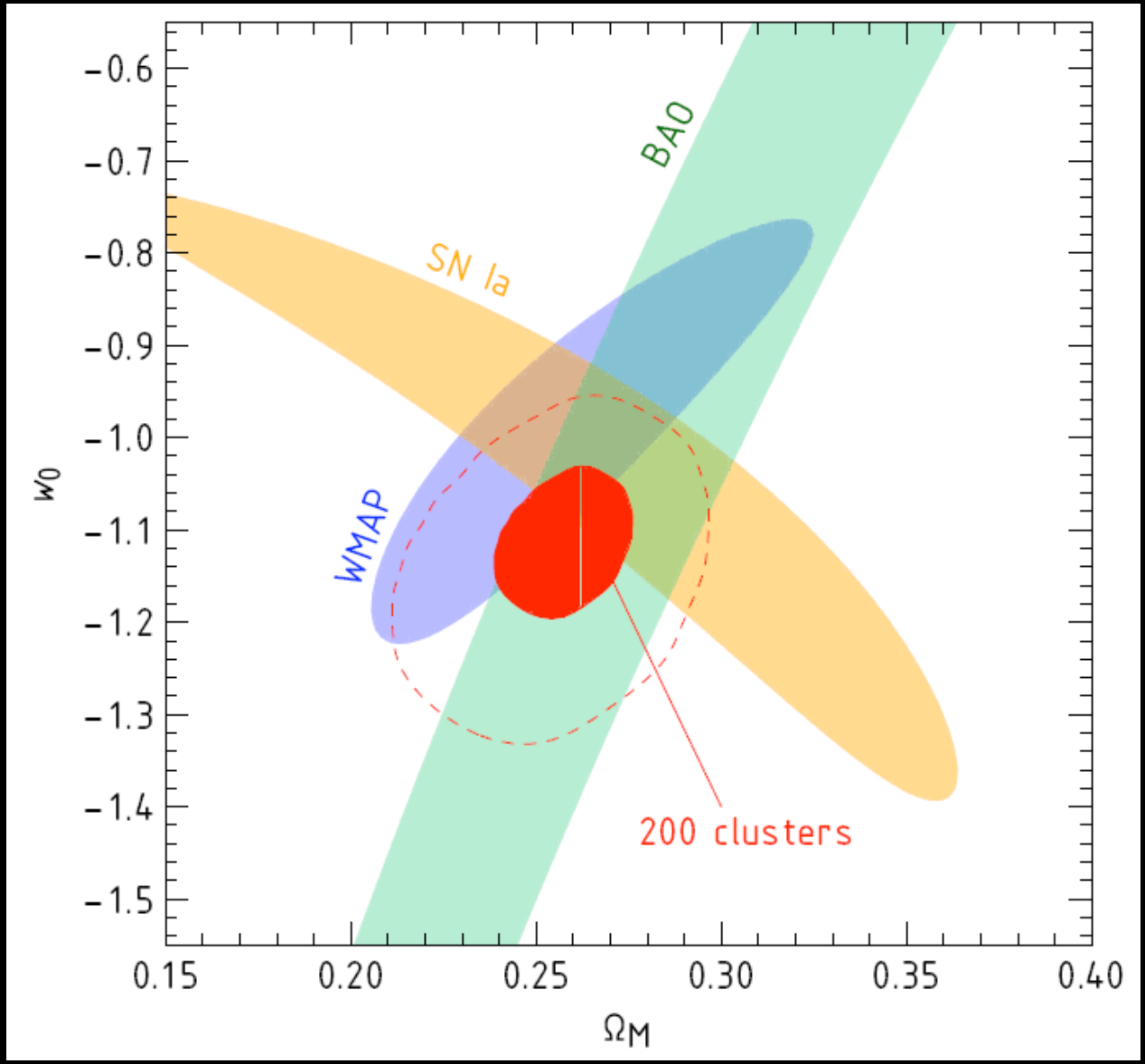
Cluster Mass Function f(z)



→There are more distant clusters for small -w !

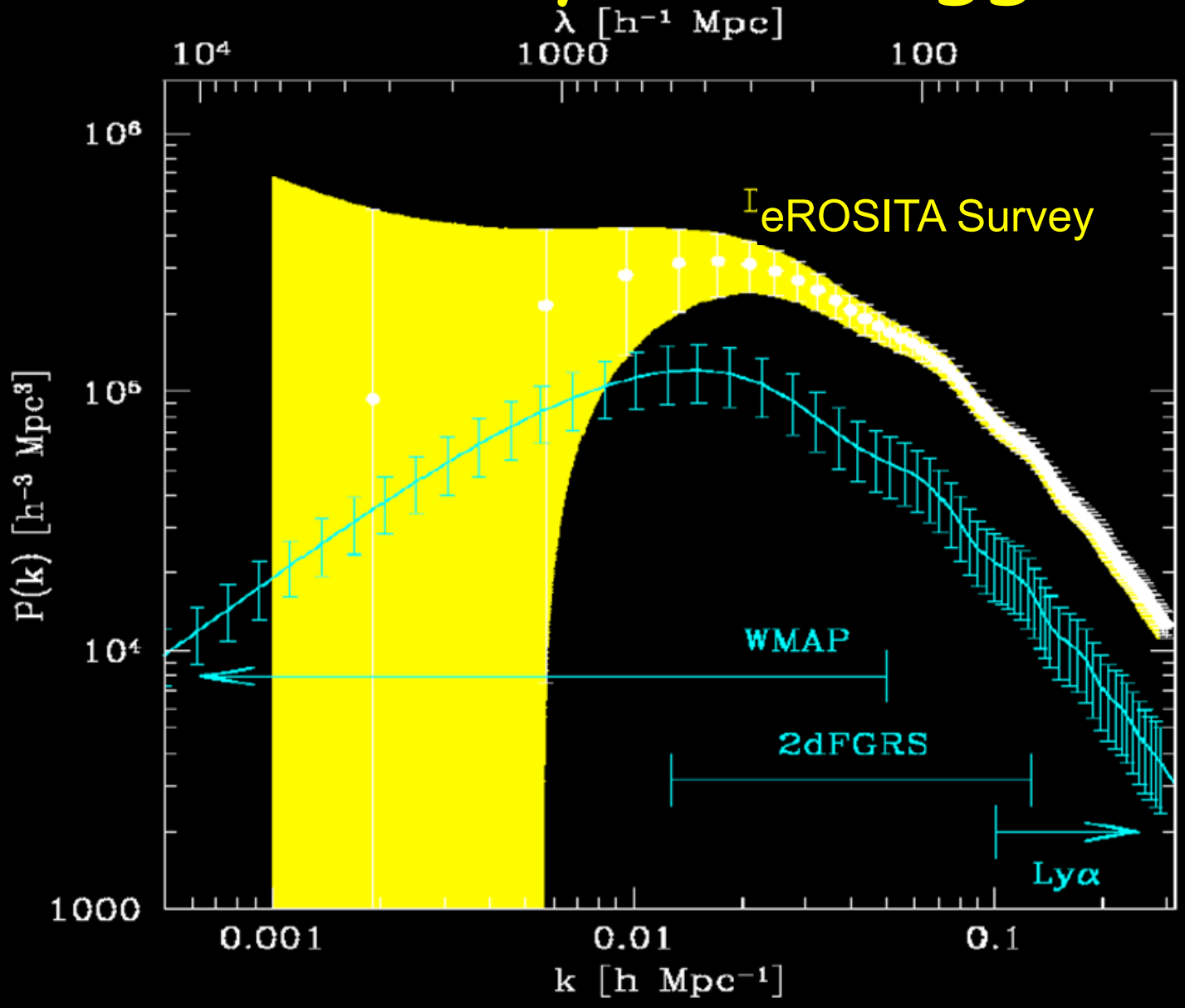
But results are very sensitive to the mass scale

Evolution of Cluster Mass Function



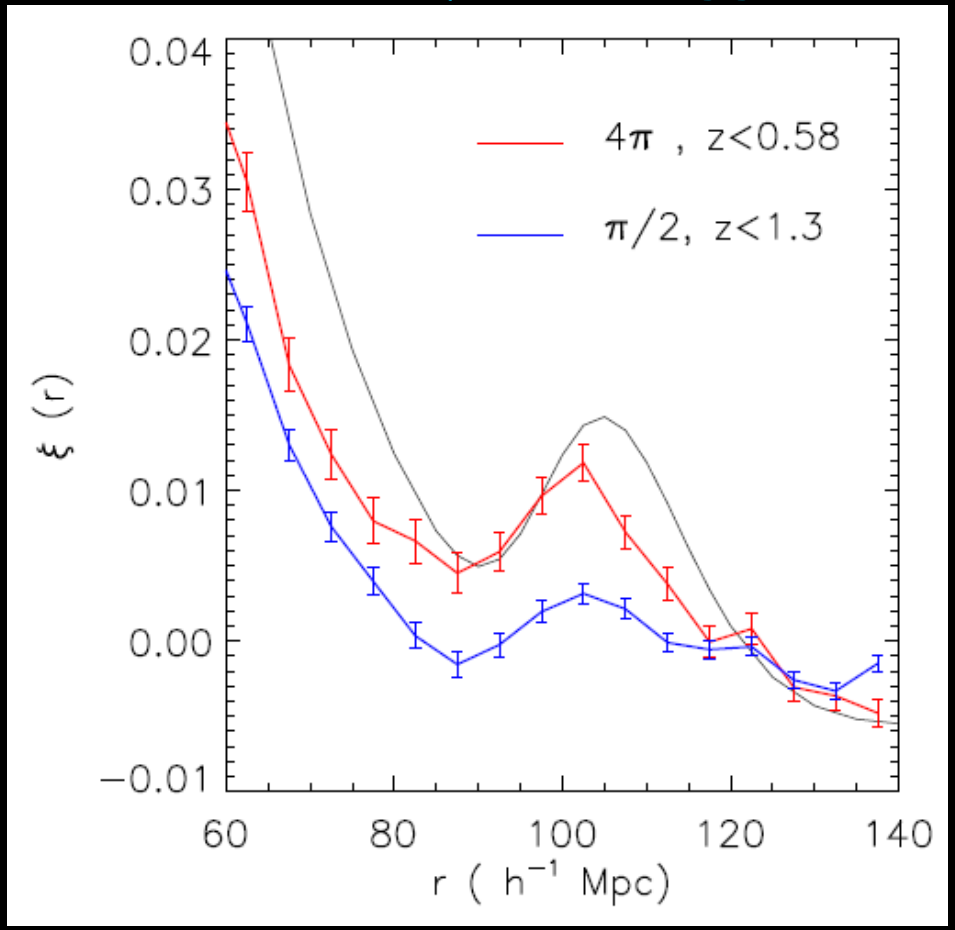
A. Vikhlinin, priv. comm.

P(k) and Baryonic Wiggles



eROSITA BAO

Cluster Baryonic Wiggles

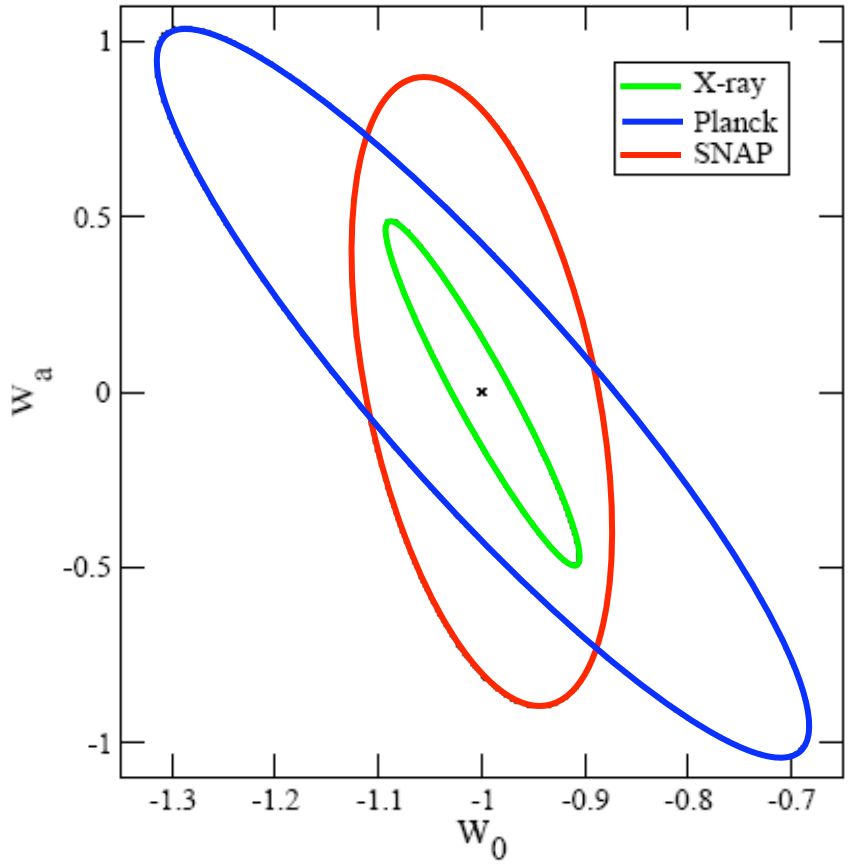


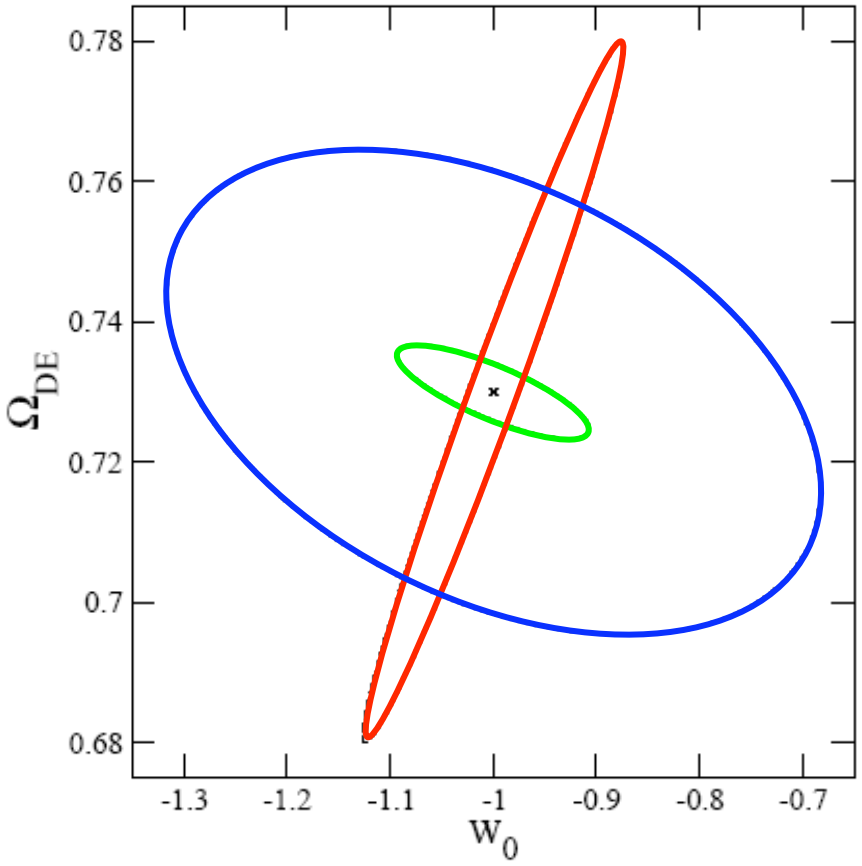
Springel et al., 2006

Constraints from 100K Cluster Survey

Time dependence of w_x

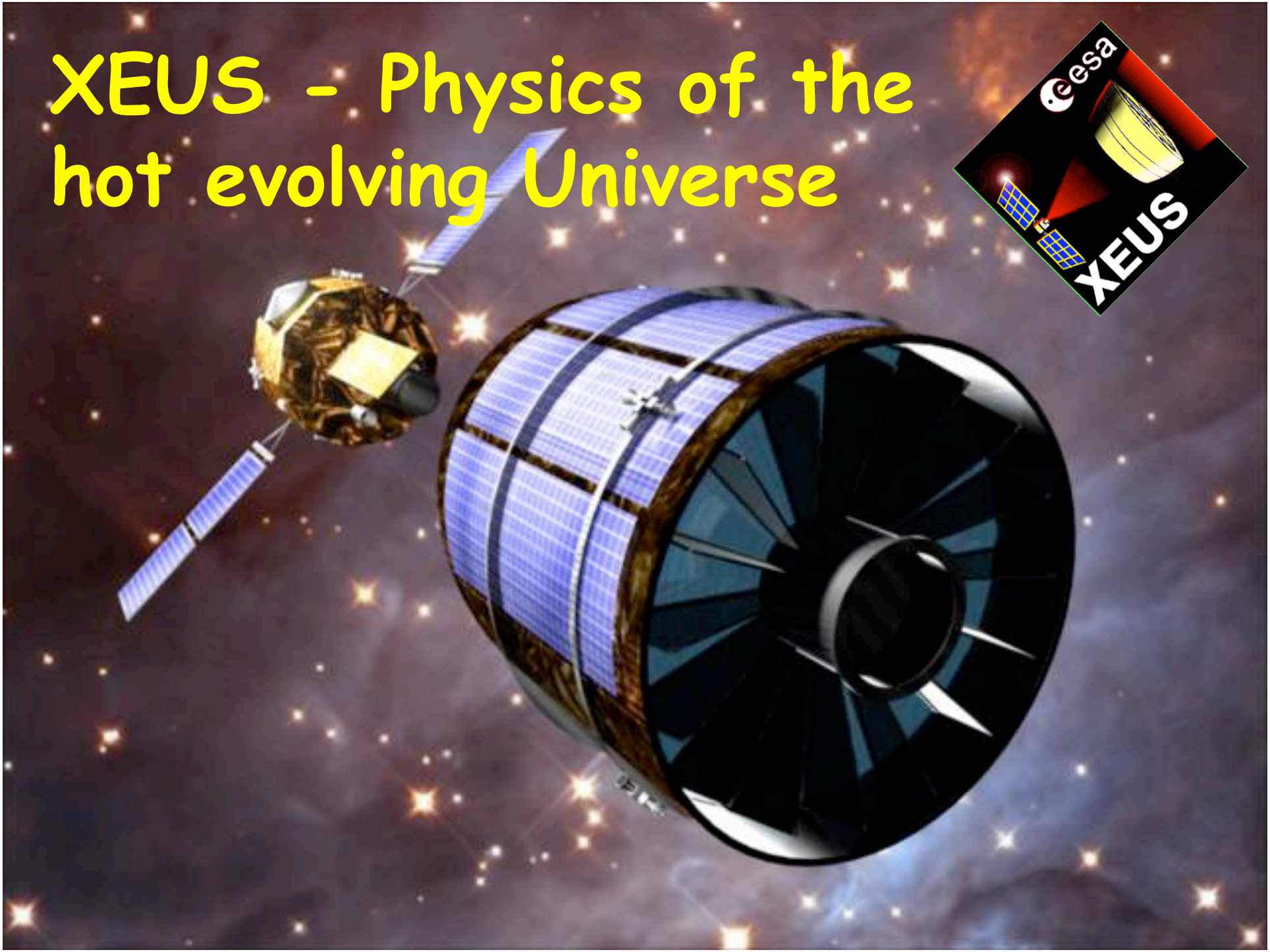
$w_{x(z)} = w_0 + w_a$ $\qquad p(z) = w_x(z) * \rho(z)$

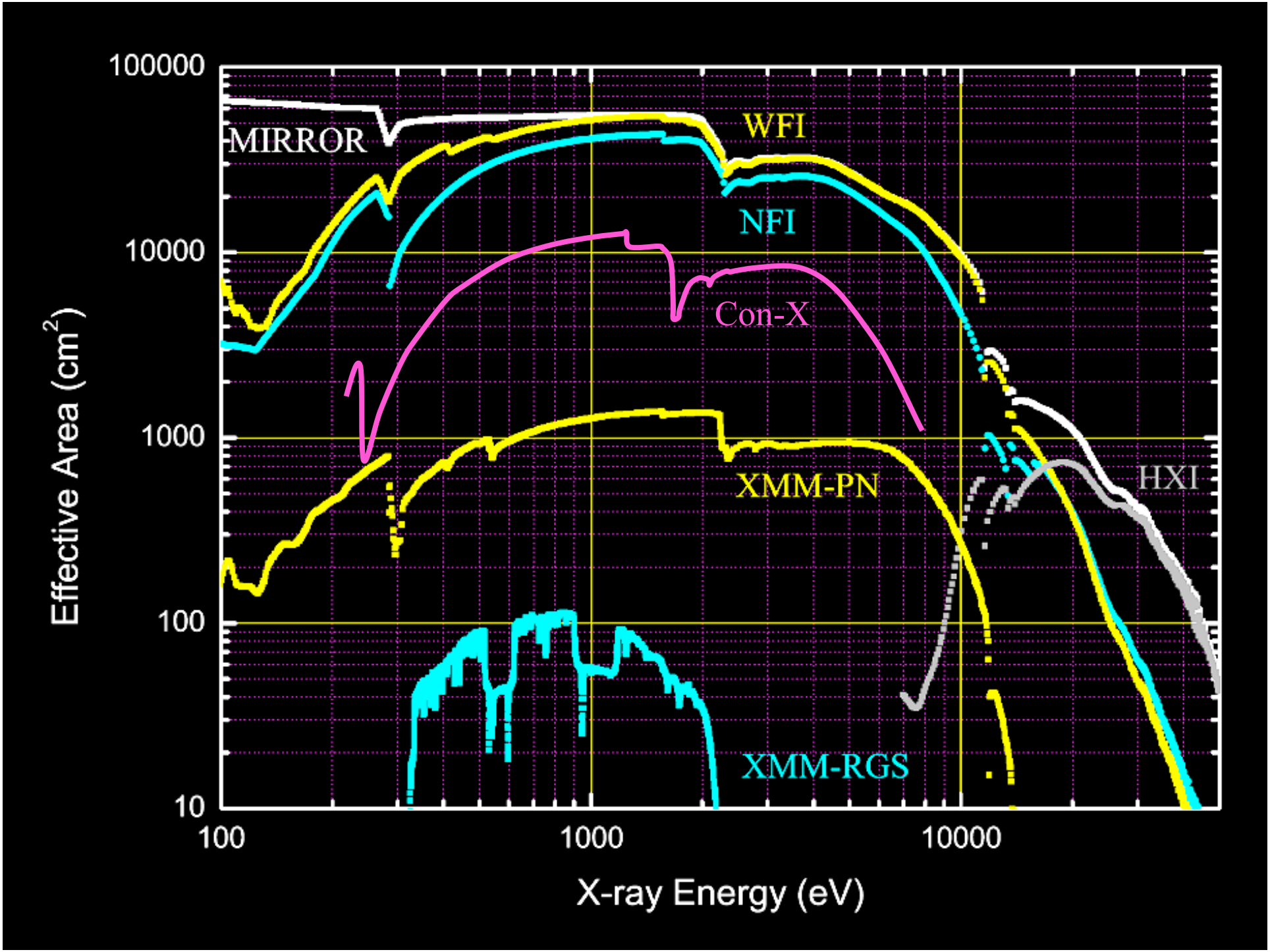




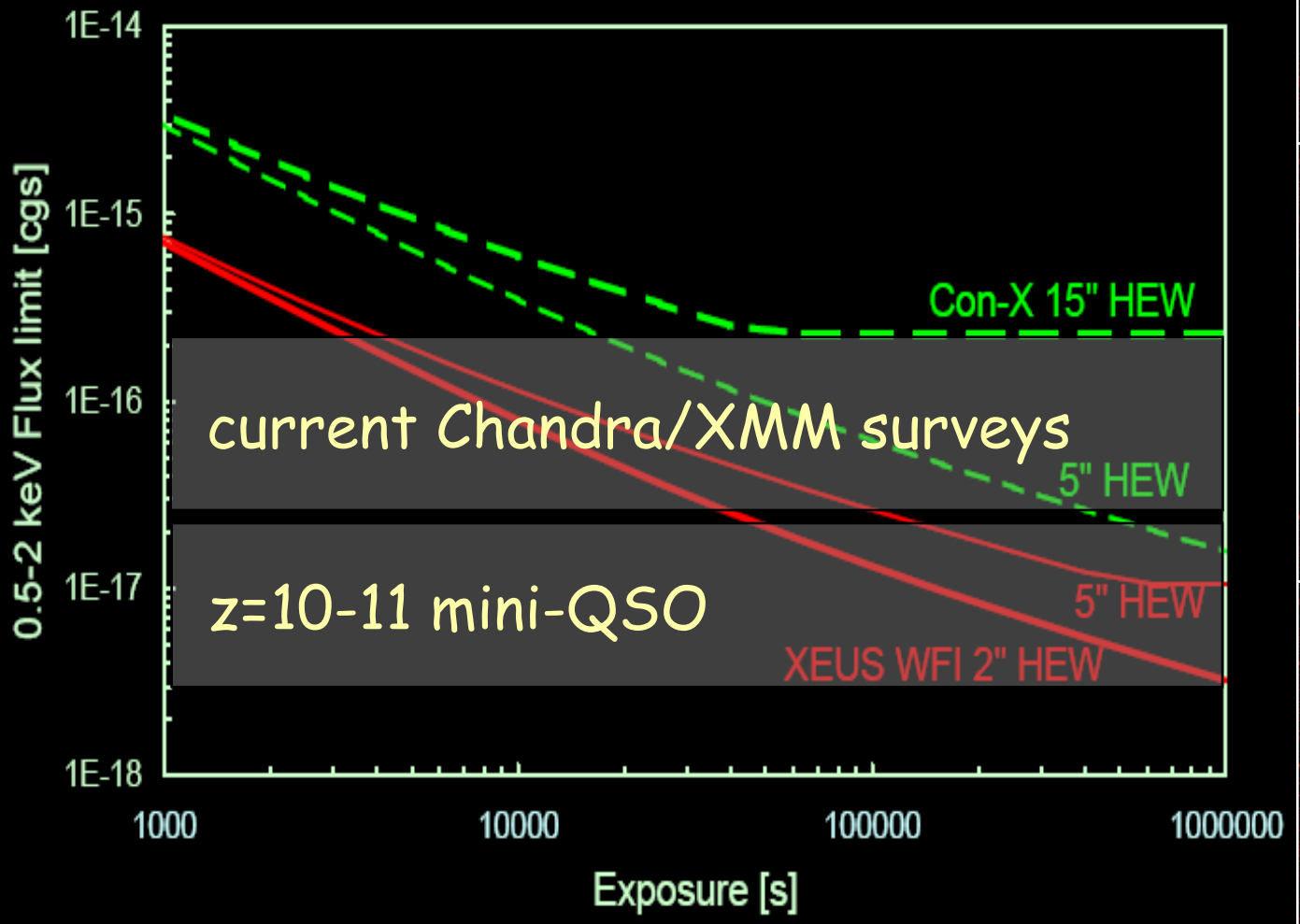
Results from the White Paper submitted to the NASA/DOE Dark Energy Task Force: Haiman et al., 2005, astro-ph/0507013

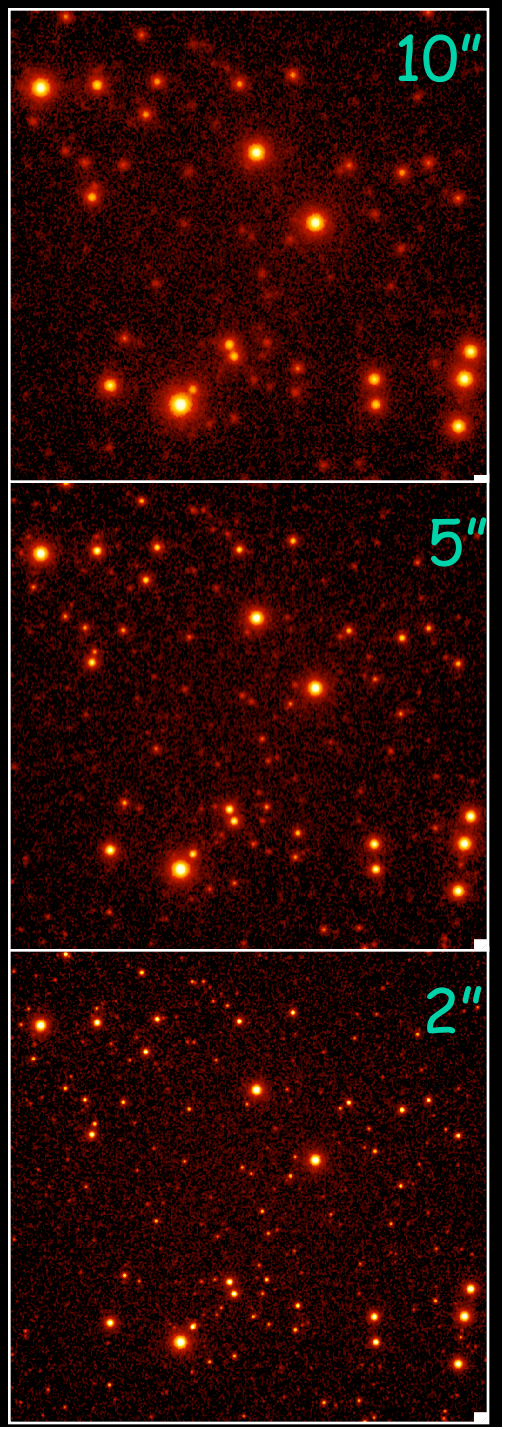
XEUS - Physics of the hot evolving Universe

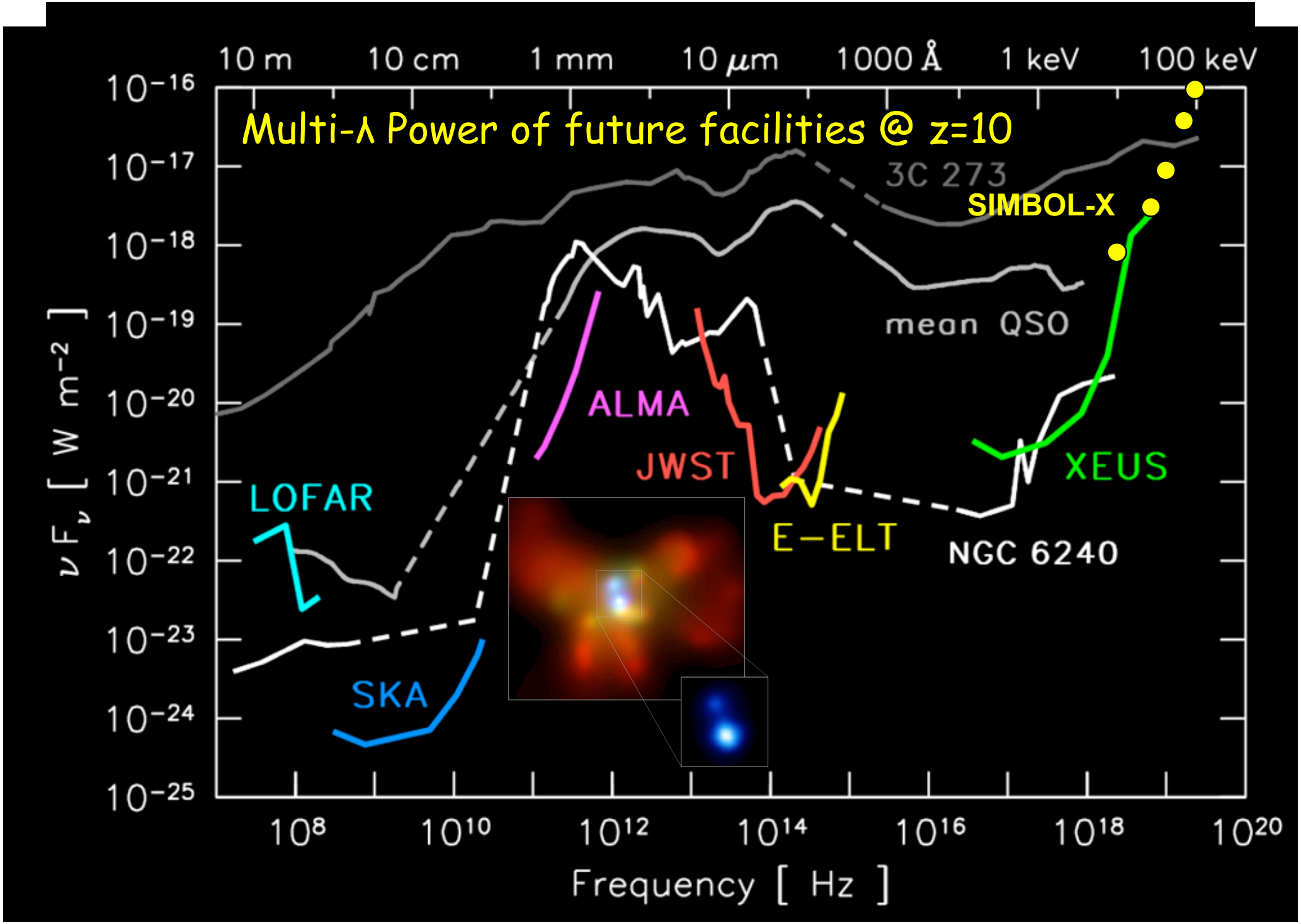



100000
10000
1000
100
10
Effective Area (cm^2)
100
1000
10000
X-ray Energy (eV)
MIRROR
WFI
NFI
Con-X
XMM-PN
HXI
XMM-RGS

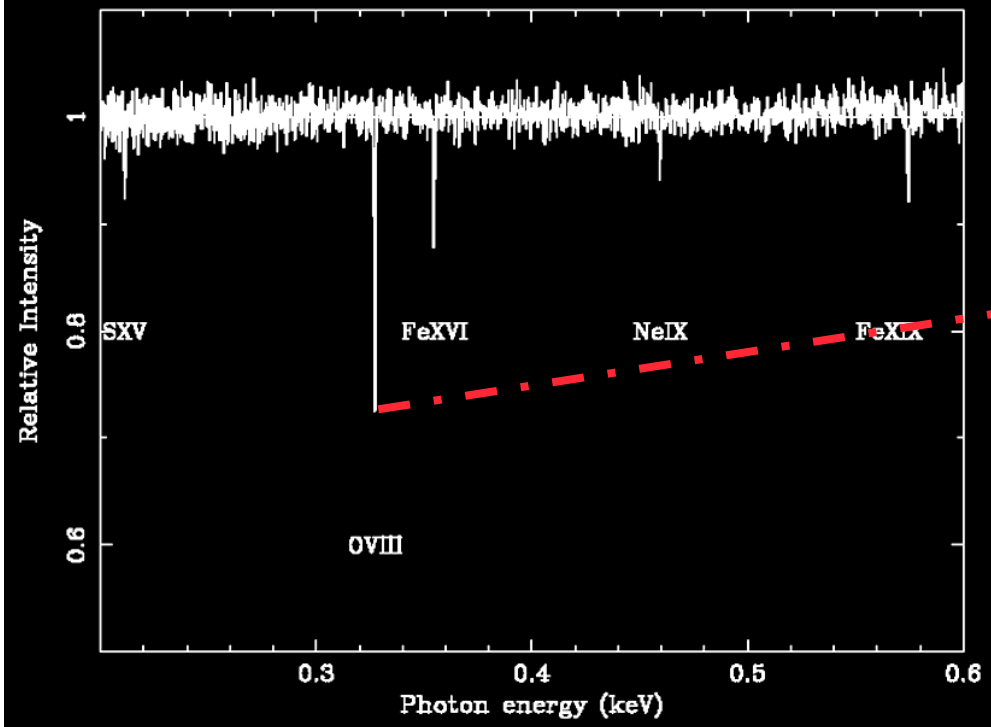
Mission Sensitivity & Angular resolution

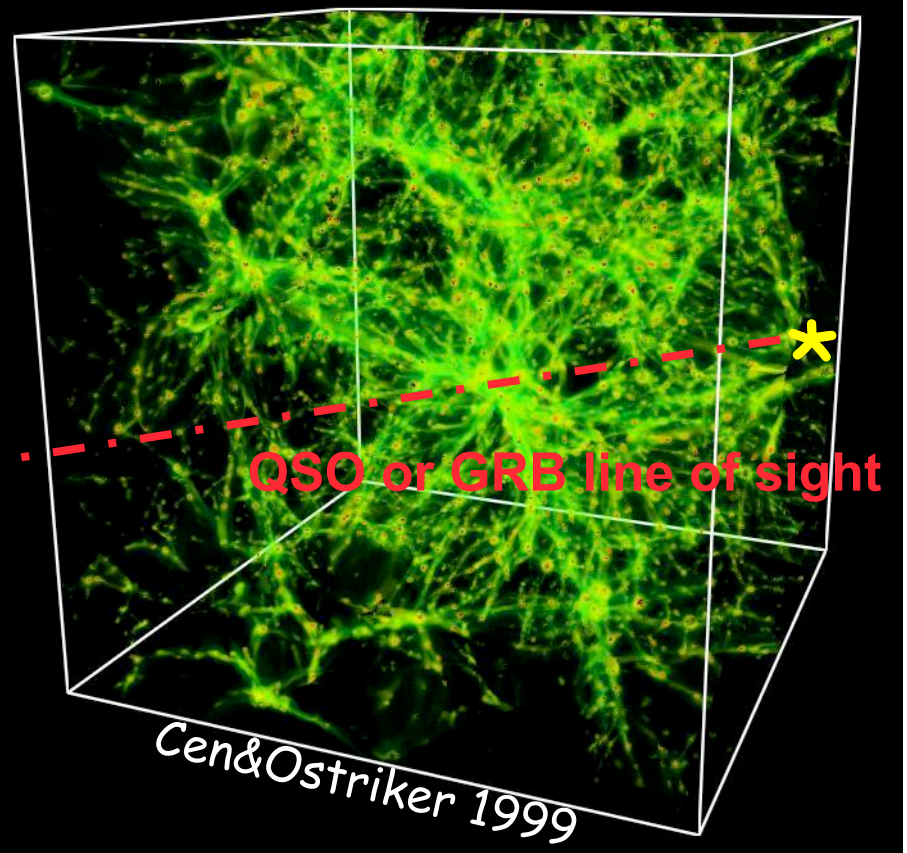





Multi-λ Power of future facilities @ z=10
10 m
10 cm
1 mm
10 μm
1000 Å
1 keV
100 keV
3C 273
SIMBOL-X
mean QSO
ALMA
JWST
XEUS
LOFAR
E−ELT
NGC 6240
SKA
νF_ν [W m^-2]
Frequency [Hz]

Tracer of Baryons

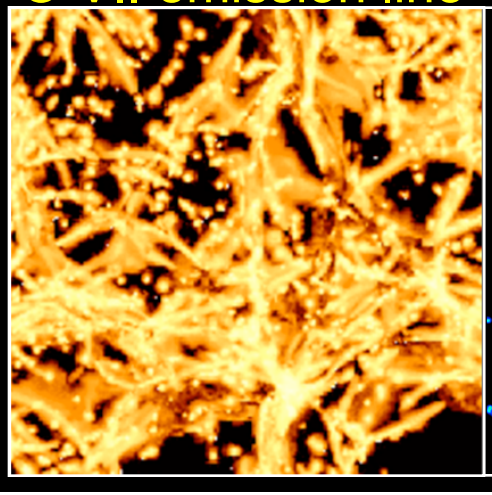




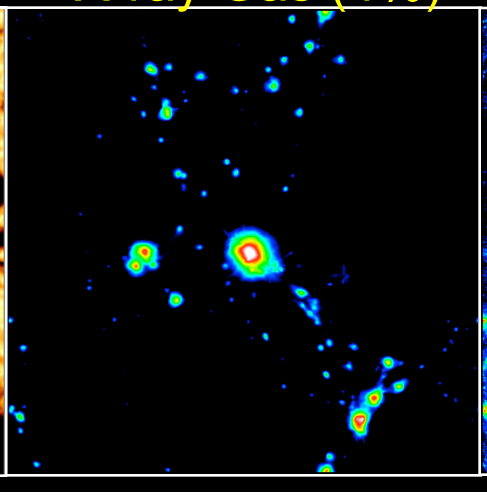
X-ray forest

Warm/hot IGM in absorption at high z and in emission at low z (XEUS)

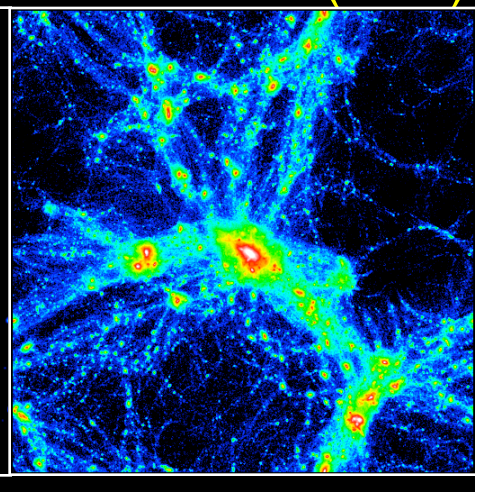
O VII emission line



X-ray Gas (4%)

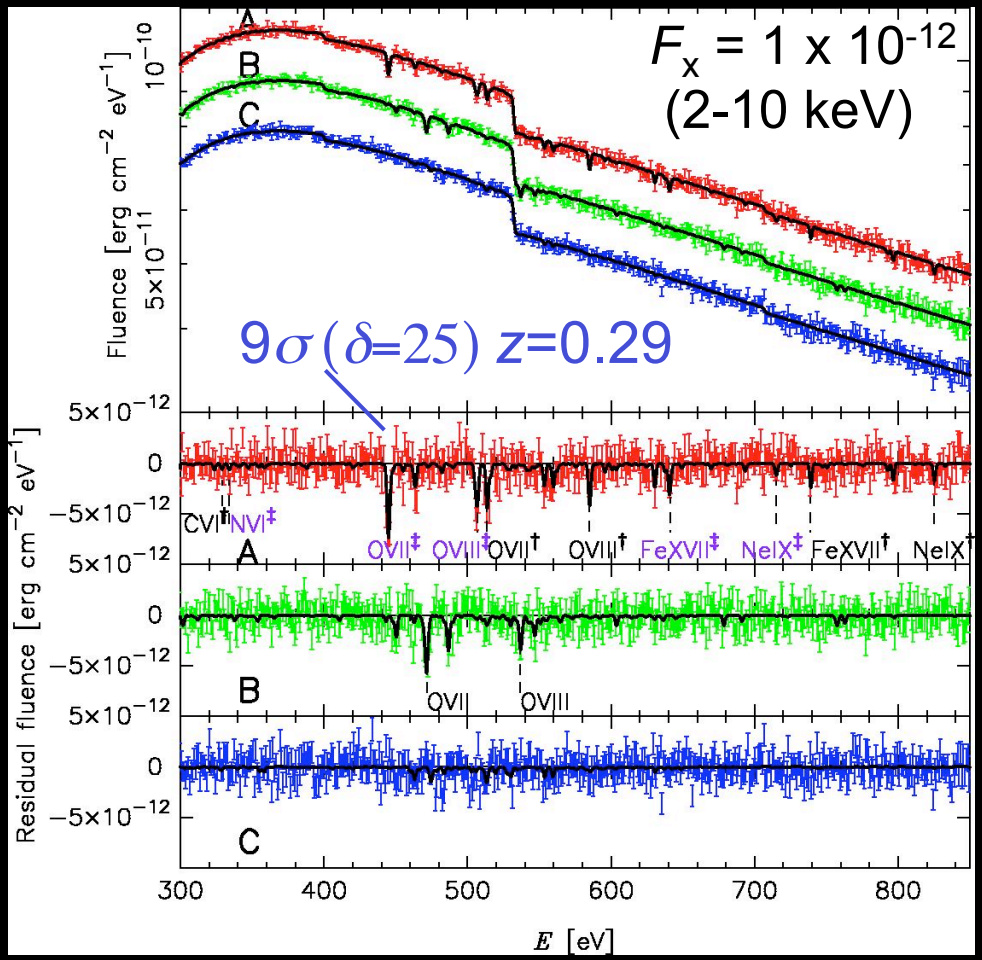


Dark Matter (23%)



XEUS Simulations

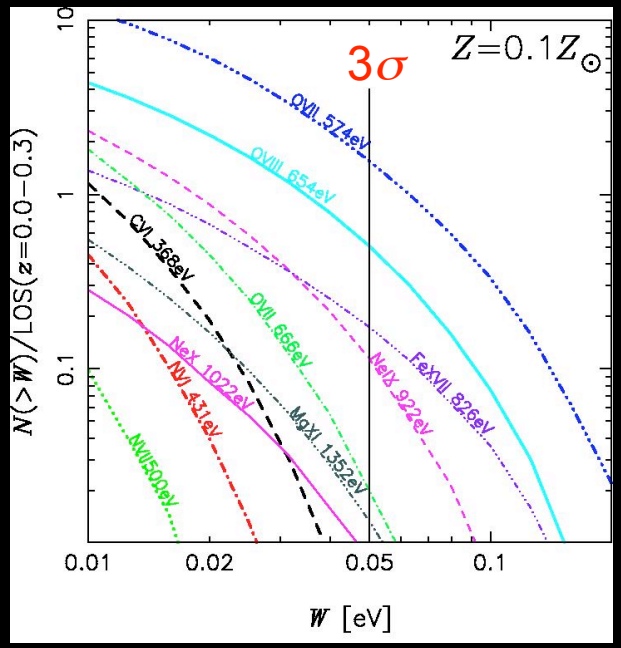
Courtesy T. Ohashi, WHIM conference



Expected number of absorption system per LOS

	$S/N \geq 3$
OVII (574 eV)	1.71
OVIII (654 eV)	0.43
OVII and OVIII	0.41

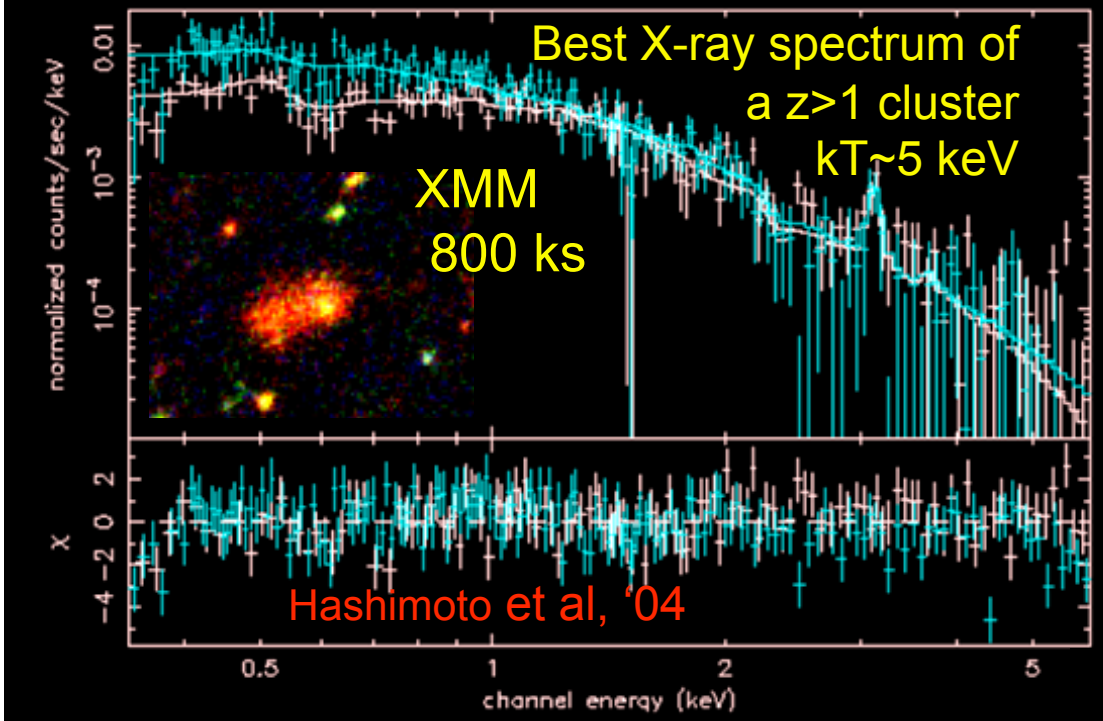
for 30 ksec obs.

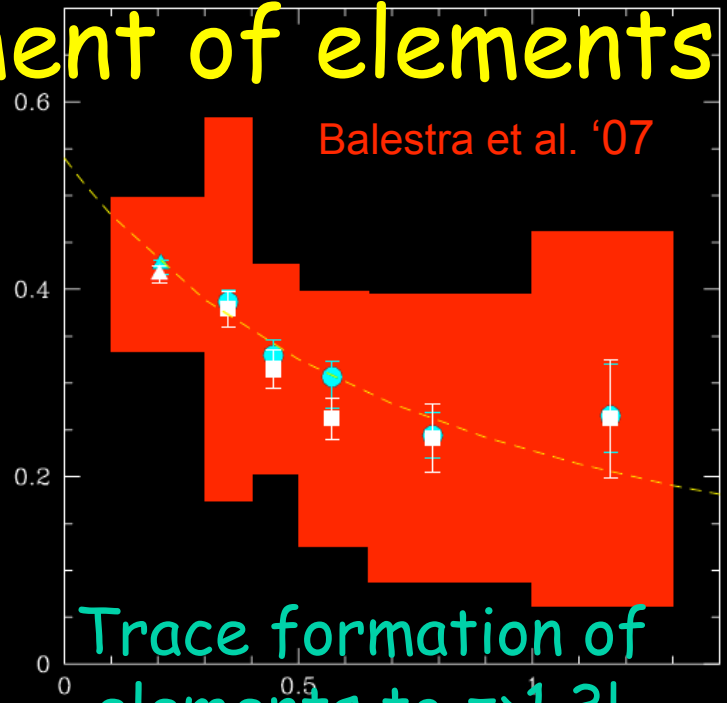


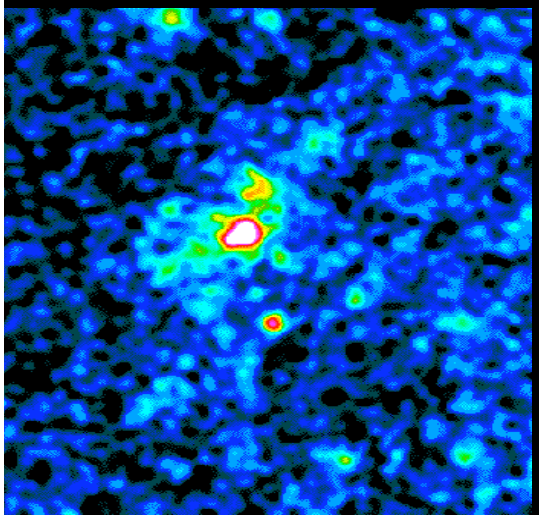
$$N_{\mathrm{OVII}} = 1.3\times10^{15}\,(EW/0.1\mathrm{eV})\,\mathrm{cm}^{-2}$$

EW=0.05 eV 3σ for 30 ksec with XEUS

Early clusters: enrichment of elements

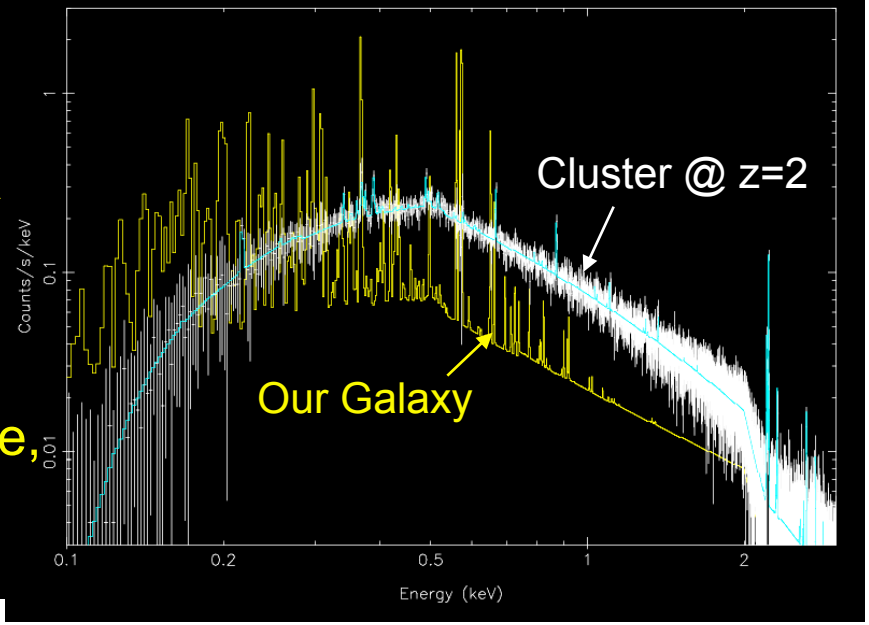




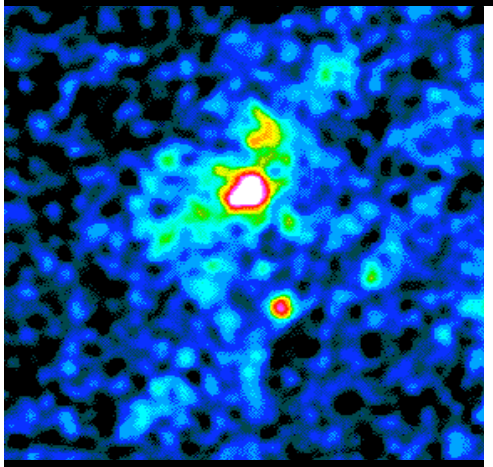


XEUS Simulation of a
5 keV cluster at z=2

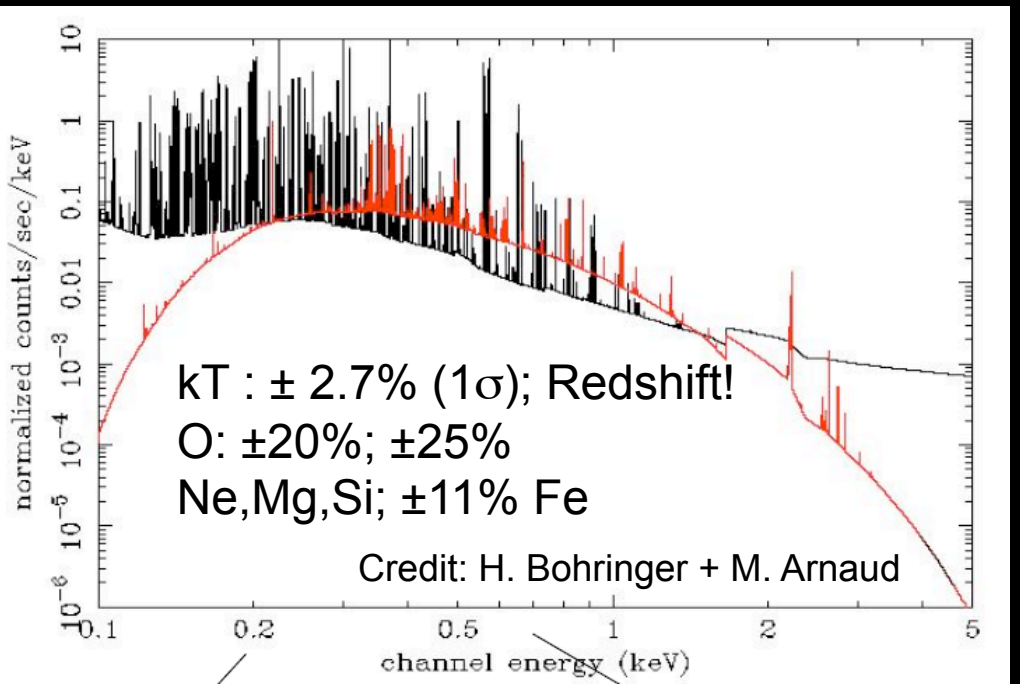
Element abundances
of O, Ne, Mg, S, Si, Fe,
…



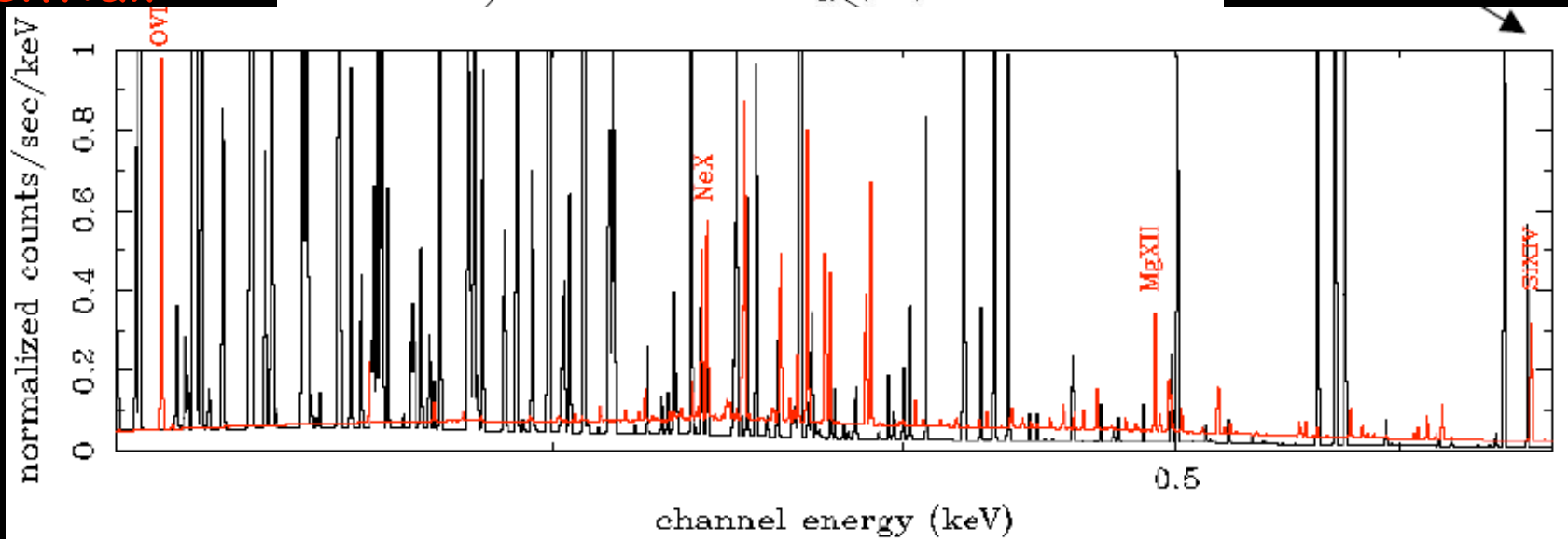
First groups at z~2



High energy resolution essential!



2 keV cluster
log L_{bol}=43.7
@ z=2
100 ksec
XEUS NFI



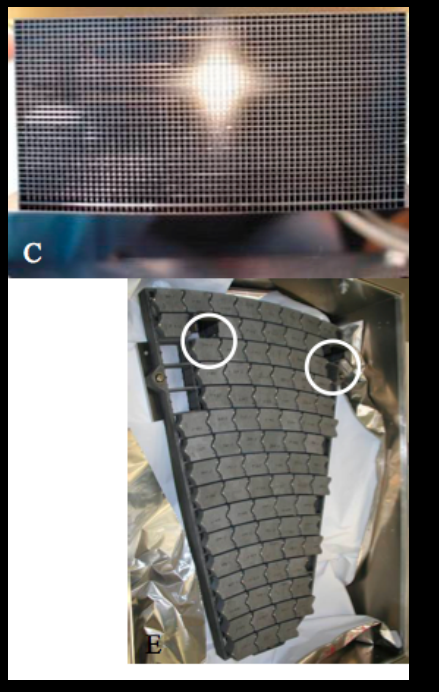
XEUS - Mission Profile

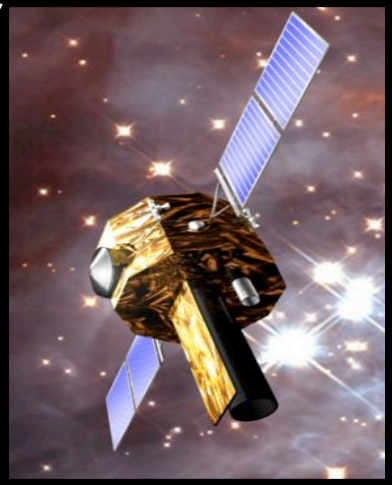
Separate Mirror and Detector Spacecraft.

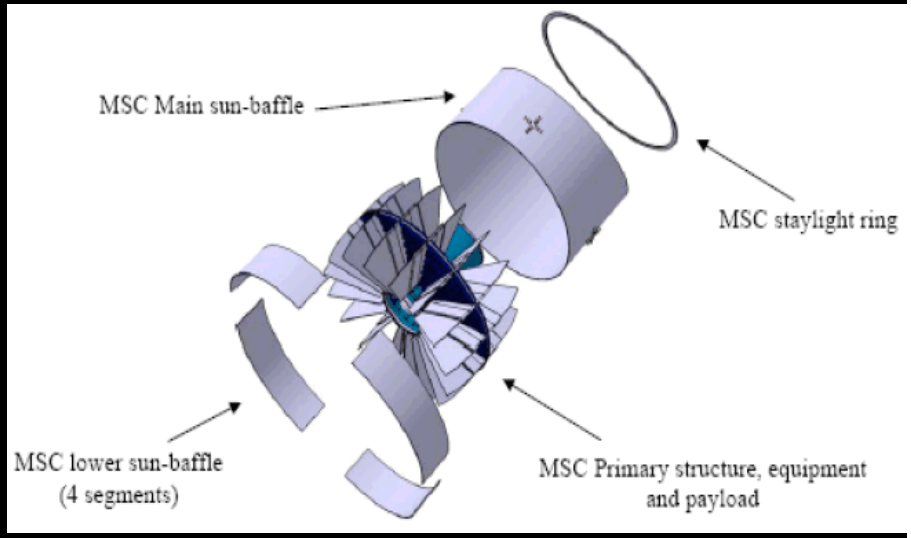
35 m focal length maintained by Formation Flying

Both spacecraft launched by a single Ariane 5 to L2

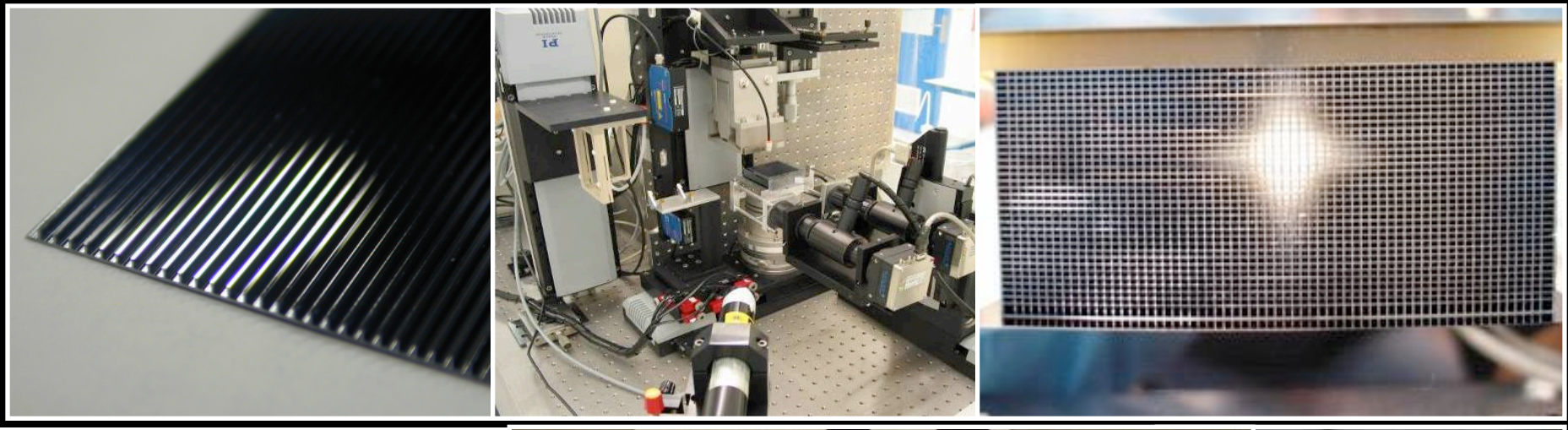
Five years science operations







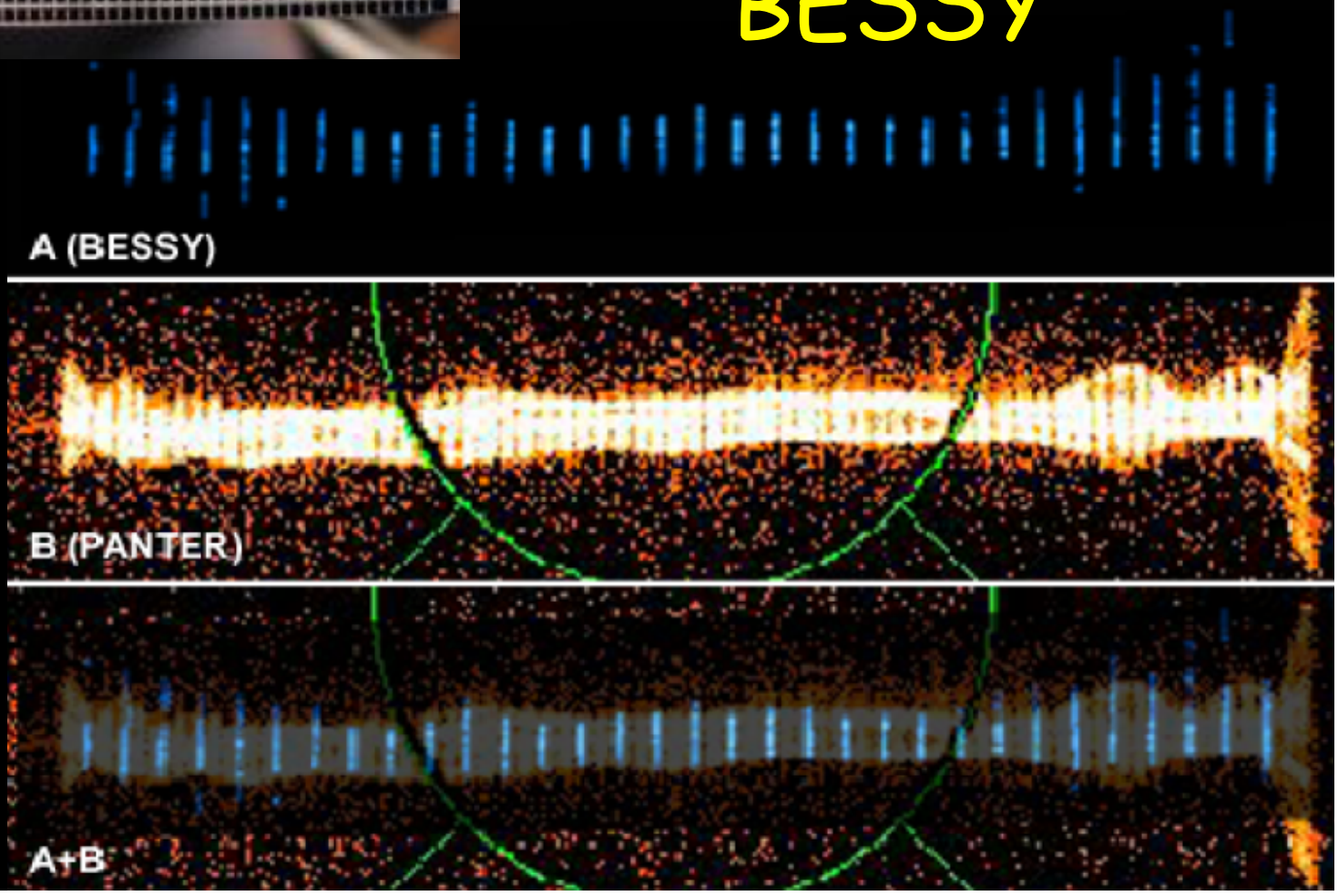
Optics development status



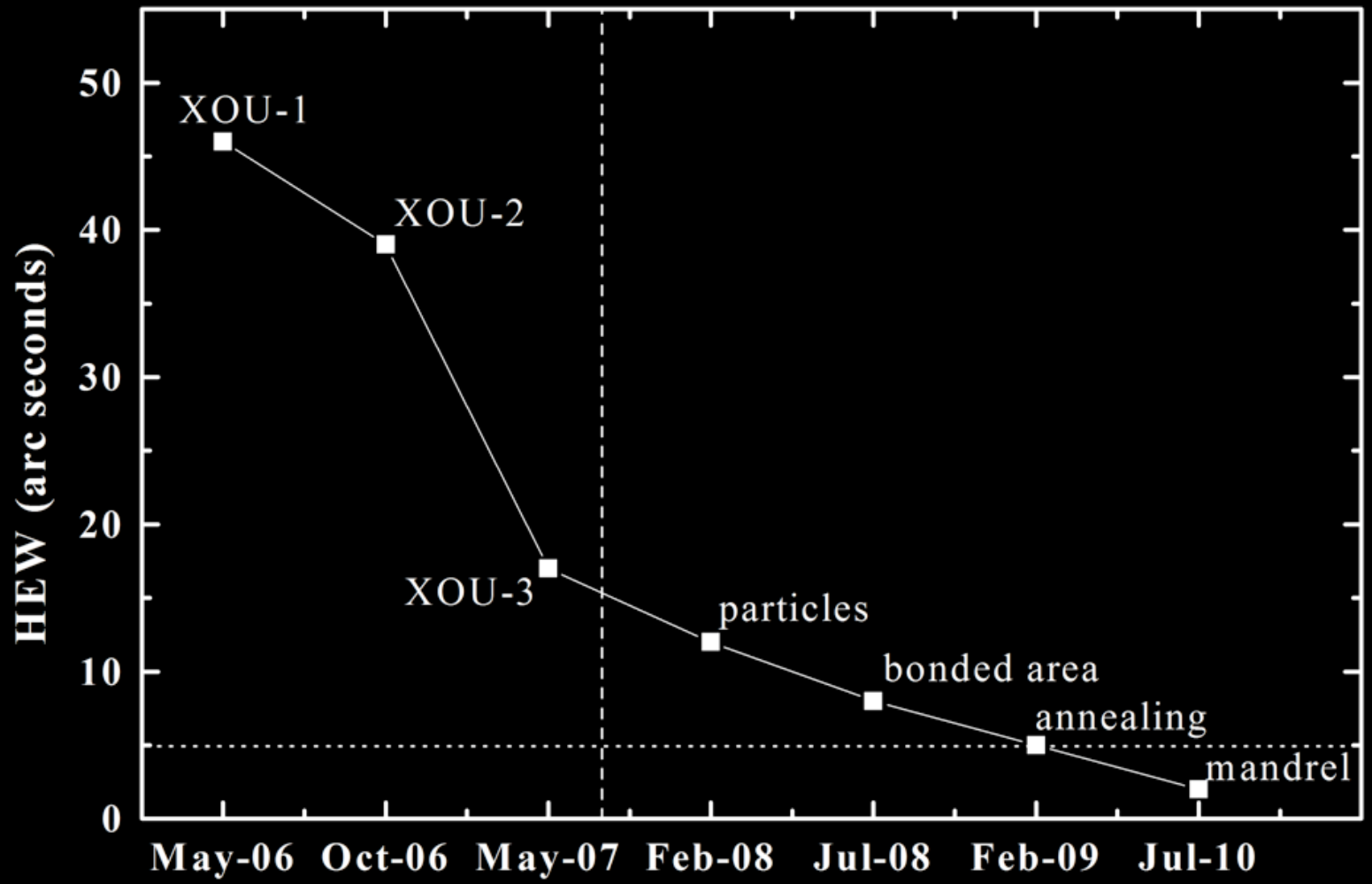
XEUS Petal at ESTEC

ESTEC, January 18, 2008

Micropore optics measured at Panter and at BESSY



HPO Development status & outlook



Summary & Outlook

- SRG/eROSITA will provide powerful surveys for >100000 clusters which will be the basis for studies of cluster evolution and Dark Energy.
- Dark Energy constraints will be competitive with and complementary to several other „level four" DETF surveys planned in the next decade.
- A large future flagship X-ray mission (NGXT) is extremely important to push further into the Early Universe and most likely have to be done in global cooperation.

Thank you very much for your attention!